PRODUCTION RECOMMENDATIONS FOR GREENHOUSE FLORICULTURE

Publication 370

Ministry of Agriculture,
Food and Rural Affairs

Ontario

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Discard old editions of this publication. Each year the appropriate sub-committee of the Ontario Pest Management Research and Services Committee reviews the pesticides listed in this publication. To the best knowledge of the committee, at the time of printing, the pesticide products listed in this publication were:

- federally registered

- classified by the Ministry of the Environment (MOE)

The information in this publication is general information only. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) does not offer any warranty or guarantee, nor does it assume any liability for any crop loss, animal loss, health, safety or environmental hazard caused by the use of a pesticide mentioned in this publication.

This publication lists a number of brand names of pesticides. It is neither an endorsement of the product nor a suggestion that similar products are ineffective.

The Pesticide Label

Consult each product label before you use a pesticide. The label provides specific information on how to use the product safely, hazards, restrictions on use, compatibility with other products, the effect of environmental conditions, etc.

The pesticide product label is a legal document. It is against the law to use the product in any other way.

Federal Registration of Pesticide Products

The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticide products for use in Canada based on following an evaluation of scientific data to ensure that the product has merit and value, and the human health and environmental risks associated with its proposed use are acceptable.

1. **Full Registration**
   Pesticide registrations are normally granted for a period of five years, subject to renewal.

2. **Conditional Registration**
   Conditional registration may be granted for a specified, limited time period, where the registrant agrees to produce additional scientific or technical information, or the pesticide is used for emergency control of a serious pest outbreak.

Maximum Residue Limits

The PMRA has established maximum residue limits (MRLs) for pesticides. Processors or retailers may demand more restrictive limits. Growers should seek advice of their intended market to determine if more restrictive limitations apply. Keep accurate and up-to-date records on pesticide use in each crop.

Supplemental Labels

You MUST obtain a supplemental label and follow all the label directions when PMRA approves new uses for a registered pesticide that do not appear on the current label.

Examples of when you must use a supplemental label include:

- **Emergency Use Registration**

- **Minor Use Label Expansion**

You can obtain a copy of a supplemental label from the pesticide manufacturer or pesticide vendor, the grower association that sponsored the emergency registration or minor use, from OMAFRA or PMRA's Pest Management Information Service.

For more information on the federal registration status check the PMRA website at *www.pmra-arla.gc.ca* or call 1-800-267-6315.

Regulation of Pesticides in Ontario

The MOE is responsible for regulating pesticide sale, use, transportation, storage and disposal in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 63/09.

All Pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 63/09, which are available on the e-laws website at *www.e-laws.gov.on.ca* or by calling ServiceOntario Publications Toll-Free number: 1-800-668-9938 or 416-326-5300.

Classification of Pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to the MOE, the classification of pesticide products before they can be sold or used in Ontario. Once approved by the MOE, classified products are posted on the MOE website: *www.ene.gov.on.ca*.

Certification and Licensing

Growers and Their Assistants

For information about certification for growers and training for assistants, check the Ontario Pesticide Education Program website: *www.opep.ca* or call 1-800-652-8573.

Commercial Applicators and Their Assistants

For more information about exterminator certification and licensing and technician training, check the Ontario Pesticide Training & Certification website at *www.ontariopesticide.com/OPTC/default.htm* or call 1-888-620-9999 or 519-674-1575.

Cette publication est aussi disponible en français.

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Need technical or business information?

Contact the Agricultural Information Contact Centre at:
1-877-424-1300 or ag.info.omafra@ontario.ca

Looking for greenhouse floriculture production recommendations on the Internet?

www.ontario.ca/crops

It's one-stop shopping for factsheets, articles and photos regarding the production and management of Ontario's greenhouse floriculture crops.

Acknowledgements

The recommendations in this publication have been prepared in consultation with Ontario Pest Management Services Committee (Greenhouse Floriculture Subcommittee), and registrants.

This publication contains pesticide products registered on greenhouse ornamental crops. Information on ordering OMAFRA publications is found on the inside back cover of this book. Supplements to this publication will be posted to the OMAFRA website.

Cover Image: The small centre photo on the front cover of this publication is courtesy of Flowers Canada Ontario Inc. and Pick Ontario.

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1. Using Pesticides in Ontario

This is a generic chapter. Some of the information in this chapter may not apply to all crops.

Read the latest product label before using a pesticide! Review the Grower Pesticide Safety Course Manual. Keep detailed spray records.

Federal Registration of Pesticides

Before a pesticide can be sold or used in Ontario, it must be registered under the federal *Pest Control Products Act* (PCP Act) and be classified under the provincial *Pesticides Act*. The Pest Management Regulatory Agency (PMRA) of Health Canada registers pesticides for use in Canada following an evaluation of scientific data to ensure that the product has merit and value. It also ensures that the human health and environmental risks associated with its proposed use are acceptable.

The PMRA re-evaluates registered pesticides to determine whether today's health and environmental protection standards are still met when following the label directions. Outcomes of a re-evaluation can be:

- no change in the registration
- label amendments (e.g. changes to personal protective equipment requirements, re-entry intervals and buffer zones)
- modifications to existing maximum residue limits (MRLs)
- elimination or phasing-out of certain uses or formulations
- no further acceptance of the registration

The pesticide label is a legal document. It prescribes how the pesticide can be legally used. Off-label use is prohibited. It is against the law to use the pesticide in any other way or on any other crop or pest than as specified on the label. Labels for all registered pesticides are under Label Search on the PMRA website at *www.pmra-arla.gc.ca*. Ensure you have the most current label and are aware of any re-evaluation decisions.

Regulation of pesticides in Ontario

The Ministry of the Environment (MOE) is responsible for regulating the sale, use, transportation, storage and disposal of pesticides in Ontario. Ontario regulates pesticides by placing appropriate education, licensing and/or permit requirements on their use, under the *Pesticides Act* and Regulation 63/09. All pesticides must be used in accordance with requirements under the *Pesticides Act* and Regulation 63/09, which are available on the e-laws website at *www.e-laws.gov.on.ca* or by calling Service Ontario at 1-800-668-9938 or 416-326-5300.

Classification of pesticides

The Ontario Pesticides Advisory Committee (OPAC) is responsible for reviewing and recommending to MOE the classification of pesticide products before they can be sold or used in Ontario. Pesticide products are classified on the basis of their toxicity, environmental or health hazard, persistence of the active ingredient or its metabolites, concentration, usage, federal class and registration status. This classification system provides the basis for regulating the distribution, availability and use of pesticide products in Ontario. Once approved by MOE, classified products are posted on the MOE website at *www.ene.gov.on.ca*.

The Ontario pesticide classification system changed from 6 Schedules to 11 Classes (Regulation 63/09).

Certification and Licensing

Growers and their assistants

For information about certification for growers and training for assistants to growers, visit the Ontario Pesticide Education Program website at *www.opep.ca* or call 1-800-652-8573.

For more information about pesticide regulations, certification and licensing see:

- Inside front cover of this publication
- Pest Management Regulatory Agency (PMRA) website: *www.pmra-arla.gc.ca*
- PMRA Pest Management Information Service: 1-800-267-6315 (from within Canada) or 1-613-736-3799 (from outside Canada)
- Ontario Ministry of the Environment (MOE) website: *www.ene.gov.on.ca*
- Regional MOE Pesticides Specialist (See Appendix B. *Ontario Ministry of the Environment – Regional Offices Contact Information,* on page 129)
- Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) website: *www.ontario.ca/omafra*
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) website: *www.opep.ca*
- Ontario Pesticide Training & Certification website: *www.ontariopesticide.com/OPTC/default.htm*

Commercial applicators (exterminators) and their assisting technicians

For more information about exterminator licensing and technician training, visit the Ontario Pesticide Training & Certification website at *www.ontariopesticide.com/OPTC/default.htm* or call 1-888-620-9999 or 519-674-1575.

Pesticide Application Information

When you decide to use a pesticide, choose the most appropriate formulation and application method for your situation. Use only a properly calibrated sprayer. Choose less toxic alternatives when possible. Take all possible precautions to prevent the exposure of people and non-target organisms to the pesticide. Read the most current pesticide label thoroughly before application. The label provides important information, such as:

- directions for use (rates of application, crops it can be used on, target pests, crop rotation restrictions, total number of applications, droplet size/nozzle type, application equipment, timing and ideal weather conditions)
- required personal protective equipment
- health hazards and toxicity
- re-entry intervals
- buffer zones
- special warnings
- steps to be taken in case of an accident
- disposal

For more information on hazards, consult the Material Safety Data Sheet (MSDS) or contact the manufacturer.

Re-entry intervals

The re-entry interval, also referred to as Restricted Entry Interval (REI), is the period of time following a pesticide application during which workers must not enter the treatment area without wearing protective clothing and personal protective equipment. This allows any pesticide residue and vapours to dissipate from the treatment location (e.g. field), preventing the possibility of inadvertent pesticide exposure.

The PMRA reviews each pesticide to determine whether the label should include a specific re-entry interval. If the re-entry interval is not stated on the label, assume that the spray solution must be dry before re-entry can occur. Some pesticides have labels that carry a warning about working in treated crops. Follow the label recommendations. See Table 2-2. *Re-entry Intervals for Pesticides Registered for Greenhouse Use,* on page 9.

Days to harvest for food crops (preharvest intervals, pregrazing and feeding intervals)

These intervals state the minimum time that must pass between the last pesticide application and the harvesting of the crop, or the grazing or cutting of the crop for livestock feed. If you harvest a crop before the preharvest interval (PHI) has passed, there may be pesticide residues in excess of the maximum residue limits (MRLs) set by PMRA.

To avoid exceeding the maximum residue limits, always follow the directions on the label.

Buffer zones

Buffer zones are areas left untreated to protect an adjacent sensitive area, such as sensitive terrestrial and aquatic habitats, well heads, non-target crops and areas where children play.

Leave a suitable buffer zone between the treatment area and adjacent sensitive areas. Buffer zones may vary depending on the method of application (e.g. aerial, field boom, hand-held sprayer). Some pesticide labels specify buffer zone requirements. Check the pesticide label for the type of buffer zone required.

Sensitive terrestrial habitats include hedgerows, grasslands, shelterbelts, windbreaks, forested areas, woodlots, vegetative strips, etc.

Sensitive aquatic habitats include lakes, reservoirs, streams, creeks, marshes, wetlands, ponds, commercial fish ponds, etc.

Setback distances for water bodies
It is an offence under the federal *Fisheries Act* to introduce into water any material that may be harmful to fish or fish habitat. To protect these waters, applicators must determine a suitable setback distance between the area to be protected and the area where pesticide treatments are planned (if one is not specified on the pesticide label). The protected area includes the water body as well as adjacent riparian (riverbank) areas that contribute to fish food and habitat.

Protect the Environment

Protect water sources

According to the British Crop Protection Council (BCPC), between 40 and 70% of surface water pesticide contamination comes from mixing and filling areas. You should load or mix pesticides on impermeable surfaces that are safely away from watercourses or environmentally sensitive areas. Drainage and run-off should be collected and disposed of safely (*Your Guide to Using Pesticides,* BCPC 2007).

Clean your spray equipment away from wells, ponds, streams and ditches. Apply the diluted rinse water (usually at a ratio of 10 to 1) to the treatment area (crop) but do not exceed the pesticide rate recommended on the label.

Do not make a direct connection between any water supply (e.g. public supply, wells, watercourse or pond) and a spray tank. Use an anti-backflow device or intermediate system to prevent back-siphoning that could contaminate the water supply.

Immediately contain and clean up any spills to prevent contamination to water sources.

Check the pesticide label for specific instructions on water source protection.

For more information on protecting water sources, see:

- OMAFRA Factsheet *Groundwater – An Important Rural Resource: Protecting the Quality of Groundwater Supplies,* Order No. 06-115
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices – Pesticide Storage, Handling and Application,* Order No. BMP13

Prevent bee poisoning

It is important to protect bees when spraying insecticides. This is particularly important for growers of outdoor floriculture crops. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees sources of nectar for honey production.

Read each pesticide label for specific precautions regarding bees. Choose less toxic alternatives when possible. Most organophosphate and carbamate insecticides are highly toxic to bees.

Advise local beekeepers before you apply a pesticide, so that they may take additional precautions to protect their bees. Contact the Provincial Apiarist at 1-888-466-2372, ext. 63595, for a list of the beekeepers in your area. Follow guidelines regarding spray timing to prevent unnecessary poisonings. For more information on preventing bee poisoning, see the "apiculture" section of the OMAFRA website at *www.ontario.ca/crops.*

Manage drift

- Do not spray when wind speeds are high or gusty. These conditions will favour spray drift. Check pesticide labels for allowable wind speeds for spray applications. Some labels may not provide this specific information. Constantly monitor wind conditions during spraying using a good quality wind meter. Record the wind speed and direction. As wind conditions change, you may need to make adjustments to further reduce the drift potential, such as adjusting water volume upwards, minimizing nozzle-to-target distance, changing nozzle technology, changing fields because of surrounding influences or stop spraying until conditions improve.

- Do not spray during periods of dead calm. Periods of dead calm usually occur in early morning or late evening, at which time the temperature is usually cooler and the relative humidity is typically higher. The combination of these factors can result in drift-sized droplets staying in the field. When the wind picks up, these spray droplets can move away from the target area, possibly causing injury to adjacent non-target areas.
- Use the recommended sprayer output (water volume).
- Use a nozzle that will produce the appropriate droplet size if specified on the pesticide label.
- Use the most appropriate nozzle for the type of application. Where practical, use air induction/venturi nozzles, which significantly reduce drift when compared to conventional nozzles.
- Check the height of the boom to the target and minimize the distance as much as possible while still maintaining spray uniformity.
- Follow buffer zone requirements for the protection of adjacent sensitive areas as outlined on the pesticide label.
- Use spray plume protection where practical or available (hoods, shrouds, screens and air curtains).
- Use drift-reducing adjuvants in the spray tank as directed on the label.
- Use wick weeders instead of spraying when possible.
- Use non-volatile pesticide formulations or products.

For more information about spray drift, see:
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices – Pesticide Storage, Handling and Application*, Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) videos *How to Manage Spray Drift* and *Spray Drift Reduction Through Air Induction*, available at *www.opep.ca/Educational/EducationalMaterials.htm*

Pesticide Disposal

Empty pesticide containers

Never reuse empty containers. Puncture the cleaned empty containers to make them unusable.

The Ontario Empty Pesticide Container Recycling Program is available to growers and commercial applicators. Through this program, you can return cleaned and triple rinsed plastic/metal pesticide containers (up to 23 L for plastic and 20 L for metal) to pesticide container depots located throughout the province. Remove the paper booklet from the pesticide container before recycling. To locate the closest pesticide container recycling depot, call the Ontario Pesticide Education Program at 1-800-652-8573, your local dealer or municipality, or visit the CropLife Canada website at *www.croplife.ca*.

Surplus spray mix

The best way to dispose of any excess spray mix is to find other fields that require an application of this pesticide. Before spraying, check the label to make sure the pesticide is registered for use on that crop.

If you cannot find another field to spray, dilute the remaining spray mix by adding 10 parts of water for each 1 part of spray mix. The diluted solution can be safely applied to the original treated area as long as you do not exceed the pesticide rate recommended on the label. Be sure to check the label for any restrictions about crop rotation, days to harvest or surplus spray mix disposal.

Never re-spray the treated field with undiluted spray mix. Spraying an area twice will double the recommended pesticide rate. This may cause illegal pesticide residues in the harvested crop or harmful residues in the soil that can cause crop damage.

Surplus pesticides in storage

Be sure to safely dispose of pesticides that you do not need or cannot use. Options for proper disposal include:

- Contact the supplier. It is sometimes possible to return unused pesticide if it is still in its original, unopened container.

- Hire a waste hauler who is licensed under Part V of the *Environmental Protection Act* to carry hazardous wastes. Look in the Yellow Pages of your telephone directory under Liquid Waste Removal.

- Check your local paper or visit the CropLife Canada website *(www.croplife.ca)* for upcoming Obsolete Pesticide Collection Days.

- Contact your municipality to see if any waste collection days are scheduled and verify whether quantities of agricultural pesticides will be accepted.

Storing pesticides

- Ontario's *Pesticides Act* and Regulation 63/09 provide details on storage requirements for storage facilities. The storage requirements that must be followed are dependent on which classes of pesticides you store.

For more information about storing pesticides, see:
- OMAFRA Factsheet, *Farm Pesticide Storage Facility,* Order No. 07-059
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices — Pesticide Storage, Handling and Application,* Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) Grower Pesticide Safety Course Manual, available at *www.opep.ca/Educational/EducationalMaterials.htm*

Pesticide Spills

If a pesticide spill causes, or is likely to cause, an adverse effect that is greater than that which would result from the proper use of the pesticide, you must notify the **Ministry of the Environment Spills Action Centre at 1-800-268-6060** (24 hours a day, 7 days a week) and your municipality.

A spill is defined as a discharge of pollutant that is abnormal in quality or quantity, from or out of a structure, vehicle, or other container into the environment. An incident such as an overturned pesticide sprayer that results in the loss of the spray solution into the environment, is an example of a spill. A pesticide container that ruptures and leaks its contents is another example of a spill. The discharge or spraying of a pesticide in an unapproved area, commonly referred to as an overspray, is also considered a spill.

Before you begin to clean up a spill of any nature, remember to protect yourself against pesticide exposure. Wear the proper protective clothing and personal protective equipment. If the spill occurs inside an enclosed area (e.g. a pesticide storage area or a vehicle during transport), ventilate the area first. Once you have protected and/or removed yourself and other persons or animals from the spill site, take additional measures to stop the spill at the source and prevent it from spreading and/or contaminating watercourses. Specific precautions, emergency contact information and first aid procedures may be found on the label.

For minor spills, it may be possible to remediate the problem:

- **For a liquid spill** – Cover the spill with a thick layer of absorbent material such as kitty litter, vermiculite or dry soil. Sweep or shovel the material into a waste drum and dispose of the contents as you would a hazardous waste.

- **For a dust, granular or powder spill** – Sweep or shovel the material into a waste drum and dispose of the contents as you would a hazardous waste.

For major spills, it is essential to stop the spill from spreading. The cleanup guidelines above may not be appropriate for all spill situations. Once you have contained the spill, follow directions from the manufacturer and regulatory authorities on cleaning the contaminated area.

For information on preventing spills, see:
- OMAFRA Factsheet, *Ways to Avoid Pesticide Spills,* Order No. 96-025
- OMAFRA/Agriculture and Agri-Food Canada booklet *Best Management Practices - Pesticide Storage, Handling and Application,* Order No. BMP13
- Ontario Pesticide Education Program (University of Guelph Ridgetown Campus) Grower Pesticide Safety Course Manual, available at *www.opep.ca/Educational/EducationalMaterials.htm*

For pesticide poisonings and pesticide injuries call:
Poison Information Centre:
1-800-268-9017
(TTY) 1-877-750-2233

For more information, see inside back cover on *Emergency and First Aid Procedures for Pesticide Poisoning*.

2. Safe Use of Pesticides

Human Health

Risks of pesticide use

There is some risk each time a pesticide is handled. The amount of risk depends on two things — the toxicity of the pesticide and the degree of exposure.

Risk = toxicity × exposure

Toxicity

Toxicity measures how harmful or poisonous a pesticide is. There are two types of toxicity:

Acute toxicity

Acute toxicity is the toxic response that results from a single exposure to the pesticide. The symbols and words on the front panel of a pesticide label give information about the acute toxicity (See Table 2-1. *Label Hazard Symbols and Words,* on page 8).

Lethal dose 50% (LD_{50}) is a measure of acute toxicity. It is the dose (in mg of product per kg of body weight) that will kill 50% of test animals (usually rats) within a stated time (24 hours to 7 days). This is commonly measured as the acute oral LD_{50}, which refers to the chemical ingested through the mouth or nose. Dermal LD_{50} figures, or skin penetration, are also available. The LD_{50} of pesticides used in greenhouse or outdoor ornamental production is listed in Table 9-1. *Insecticide and Miticide Toxicity and Classification,* on page 95, Table 9-2. *Fungicide Toxicity and Classification,* on page 97, Table 9-3. *Growth Regulator Toxicity and Classification,* on page 98 and Table 9-4. *Herbicide Toxicity and Classification,* on page 98.

The higher the LD_{50} figure, the less toxic the product is to humans. Products with low LD_{50} ratings are highly toxic. Pest control products with high acute toxicity that are registered for greenhouse use include dichlorvos (DDVP), endosulfan (Thiodan, Thionex) and nicotine (Nicotine Smoke Fumigator).

Chronic toxicity

Chronic toxicity is the toxic response from repeated exposure to small doses of a pesticide over a longer period of time. These toxic effects may not appear for months or years after exposure. The symbols on the label do not give information about the chronic toxicity of the product. Use protective clothing and equipment to help reduce exposure and risk of chronic effects.

Exposure

Exposure is a measure of the contact with the pesticide. Workers can be exposed to the pesticide in three ways:

Dermal exposure

Dermal exposure occurs through skin or eyes. The amount and rate of pesticide that may be absorbed depends on several things, including:

- Skin condition at time of exposure: If the skin is moist, or if a rash, broken skin or scratches are present, pesticide is absorbed more easily.
- Part of the body that is exposed: Eyes, genital area, scalp and ear canals absorb pesticides at a higher rate than hands or arms. Eyes are particularly vulnerable because the tissues are very absorbent.

Respiratory exposure

Respiratory exposure (inhalation) occurs when small spray particles, dust, gases or vapours are inhaled.

Oral exposure

Oral exposure occurs when a pesticide enters the mouth or is swallowed.

Cholinesterase blood tests

Organophosphorus and carbamate pesticides can affect the human nervous system. Organophosphorus and carbamate pesticides registered for use in greenhouses or outdoor floriculture include:

- acephate (Orthene)
- carbaryl (Sevin)
- chlorpyrifos (Dursban, Pyrate)
- dichlorvos (DDVP)
- dimethoate (Cygon, Lagon)
- malathion
- naled (Dibrom)
- phosmet (Imidan)

These pesticides can reduce the levels of the enzyme acetyl cholinesterase in the serum and red blood cells. The body uses this enzyme to transmit messages through the nervous system. If cholinesterase levels fall, individuals experience symptoms such as trembling, twitching, blurred vision, and breathing and heart difficulties.

People who routinely use any organophosphorus and carbamate pesticides should have regular cholinesterase blood tests. A family doctor can arrange these tests, which are covered by OHIP. Workers should have their first test before beginning to handle these pesticides to show their baseline (normal) cholinesterase level. During the spray season, workers who spray organophosphorus or carbamate insecticides regularly for several weeks should have a cholinesterase blood test every 7–10 days. If the cholinesterase level drops to less than half of the baseline level, the worker is showing signs of pesticide poisoning and must prevent exposure to these pesticides until cholinesterase levels return to normal.

Read and Follow Pesticide Label Information

Know the hazard symbols and words

Four important symbols and words show the potential hazards of pesticides. See Table 2-1. *Label Hazard Symbols and Words,* on this page.

Check the label for special warnings about eye and skin hazards. The front panel of the label may also contain warnings that indicate whether the product is corrosive to eyes or is a skin or eye irritant.

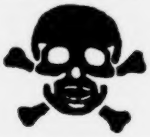
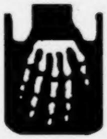
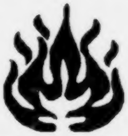
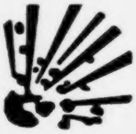
Learn about the health hazards and toxic properties of the pesticide being used. Consult the product label, Material Safety Data Sheets (MSDS) or manufacturer for this information. Check the company websites for MSDS information.

Re-Entry Periods

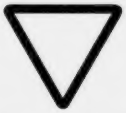
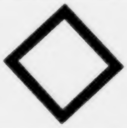
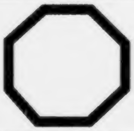
The re-entry period is the minimum amount of time that must pass between the time the pesticide was applied and the time workers can go into the treated area without wearing personal protective equipment.

Table 2–1. Label Hazard Symbols and Words

Learn these symbols and words – they could save your life!

Hazard symbol				
Signal word	Poison	Corrosive	Flammabie	Explosive

The hazard symbol always appears inside one of the shapes shown below. The shape and its warning word together indicate the degree of hazard of the pesticide. The greater the number of sides of the shape, the more hazardous the product.

Warning symbol			
	Triangular shape means low hazard (3 sides)	Diamond shape means moderate hazard (4 sides)	Octagonal shape means high hazard (8 sides)
Signal word	Caution	Warning	Danger

If workers enter treated areas without wearing protective equipment too soon after pesticides have been applied, they may experience poisoning from handling treated plants or inhaling pesticide vapours. If the label does not specify a re-entry period, then the crop can be re-entered when the spray has dried.

Some pesticides have labels that carry a warning about working in treated crops. Follow the label recommendations. The product label is always the best source for this information. Otherwise, take note of the re-entry periods listed in Table 2-2. *Re-entry Intervals for Pesticides Registered for Greenhouse Use,* on this page, which shows specific minimum intervals between application of the greenhouse registered pesticide and work in the treated crop without protective equipment.

First Aid

If an accident occurs:

1. Always protect yourself from injury first. Do not become a victim. Always put on protective clothing and equipment before entering a contaminated area or handling a contaminated victim.

2. Check to see if the victim is breathing.
   If the victim is not breathing:
   - Straighten the victim's airway and check for breaths.
   - If the victim does not begin to breathe, administer artificial respiration until the victim begins to breathe independently.
   - Do not contaminate yourself, especially if the victim has pesticide or vomit around the face or mouth. Use a face shield airway with a one-way valve. Do not breathe the exhaled air from the victim.
   - If the victim's pulse disappears, perform CPR if you are qualified to do so.

   If the victim is breathing, but unconscious:
   - Place the victim in the recovery position (on the side with the head turned slightly to one side). If the victim vomits, try to keep the airway clear.

3. Stop the exposure to the pesticide. Move the victim away from the contaminated area. Remove all contaminated clothing. Use soap and water to wash any skin exposed to the pesticide.

4. Check the four basic facts:
   - What? Identify the pesticide. Look for the label, container or leftover pesticide.
   - How much? How much product was the victim exposed to?
   - Where? How did the pesticide enter the body? Did it enter through the mouth, skin, eyes or lungs?
   - When? How much time has passed since the victim was exposed to the pesticide, and how long was the exposure? Were the symptoms immediate

Table 2–2. Re-entry Intervals for Pesticides Registered for Greenhouse Use

4 Hours (or less)	12 Hours	24 Hours	48 Hours	96 Hours
• *Streptomyces lydicus* (Actinovate) – (1 hour) • *Beauveria bassiana* (BotaniGard) • fenhexamid (Decree) • *Gliocladium catenulatum* (PreStop) • potassium bicarbonate (Milstop) • *Streptomyces griseoviridis* (Mycostop) • *Trichoderma harzianum* (RootShield)	• acequinocyl (Shuttle) • acetamiprid (Tristar) • bifenazate (Floramite) • cyromazine (Citation) • deltamethrin (DeltaGard, Decis) • diflubenzuron (Dimilin) • dimethomorph (Acrobat) • etradiazole (Truban) • fenbutatin oxide (Vendex) • iprodione (Rovral) • kinoprene (Enstar II) • pymetrozine (Endeavor) • pyridaben (Dyno-Mite) • pyriproxifen (Distance) • spiromesifen (Forbid 240 SC) • trifloxystrobin (Compass)	• acephate (Orthene) • dazomide (B-Nine, Dazide) • dichlorvos (Plantfume DDVP Smoke Fumigator) • folpet (Folpan 80 WDG) • metalaxyl (Subdue Maxx) • myclobutanil (Nova) • propamocarb hydrochloride (Previcur)	• chlorothalonil (Daconil Ultrex) • chlorpyrifos (Dursban WSP, Dursban T, Pyrate 480 EC) • endosulfan (Endosulfan 400E, Thionex EC) • naled (Dibrom)	• captan (Supra Captan 80 WDG, Maestro 80 DF, Captan 80 WDG)

or did the poisoning occur as a result of using the pesticide over a longer time?

5. Call an ambulance or the poison information centre.

6. Start the first aid treatment appropriate for the route of entry.

7. Make sure the patient gets medical attention. First aid is not a substitute for professional medical help.

Do not waste time

If you cannot answer these questions quickly, be ready to tell emergency personnel whatever you can.

Symptoms of pesticide poisoning

Mild

Headache, fatigue (tired feeling), loss of appetite, dizziness, weakness, nervousness, nausea, perspiration, diarrhea, loss of weight, thirst, moodiness, irritation of the skin, eyes, nose or throat.

Moderate

Nausea, trembling, loss of muscular coordination, excessive saliva, blurred vision, constricted throat or chest, laboured breathing, flushed or yellow skin, abdominal cramps, vomiting, diarrhea, mental confusion, perspiration, rapid pulse, cough.

Severe

Vomiting, loss of reflexes, inability to breathe or increased breathing rate, muscle twitching, tiny pupils, convulsions, unconsciousness, thirst, fever.

(Source: Grower Pesticide Safety Course manual, Ridgetown Campus, University of Guelph. Available on-line at www.opep.ca)

> If symptoms occur during or shortly after handling a pesticide, go to a hospital. Take the pesticide label, MSDS sheet or pesticide container. Do not transport the container in the passenger compartment. Refer to the Emergency Procedures for Pesticide Poisoning on the inside back cover.

Poison Information Centre

- 1-800-268-9017
- TTY 1-877-750-2233

General Precautions When Using Pesticides

Always read the label:

- before buying a pesticide
- before using a pesticide
- before storing or disposing of a pesticide

Always keep records of pesticide use.

Protection When Using Pesticides

Tell someone where the work is taking place, what pesticides are being handled and how long the job is expected to take.

Post emergency numbers, including the Poison Information Centre and Spills Action Centre, near all telephones.

Keep a list of the names and the Pest Control Products (PCP) Act registration numbers of all the pesticides handled. It is a good idea to keep a file of the pesticide label booklets for all the products used. Ensure that co-workers and family members know where this list or file is kept in case of an accident.

Have plenty of clean water, soap and paper towels – and an extra set of gloves and coveralls—nearby at all times in case pesticide contaminates clothing or skin.

Wear the correct protective clothing and equipment and be sure that all items are clean and in good repair before wearing.

Never smoke, chew tobacco, eat or drink when handling pesticides. Never carry tobacco or food in clothes. Never leave tobacco, food or beverages in areas where handling or storing pesticides.

Change clothes and wash hands and face before eating, drinking or smoking.

Wash hands before and after using the toilet. The skin in the groin area absorbs pesticides very easily.

When using fumigants:

- Remove livestock and poultry that are in the same building.
- As a safety precaution, have someone else who is wearing personal protective equipment help with the fumigation.

When using treated seed:

- Remember that seed dressings or treatments are poisonous to people and livestock.
- Do not inhale the fumes or dust when treating or handling treated seed.
- Wear neoprene or nitrile gloves.
- Wash all residue of these chemicals from skin after finishing the treatment. Chemically treated seed is poisonous.
- Never feed surplus seed to livestock.

Protective Clothing and Equipment

Choose and wear the appropriate protective clothing and equipment. Make sure protective clothing and equipment are clean, fitted properly, in good repair, and in working condition. The appropriate protective clothing and equipment for workers depends on:

- the pesticide being used — read the precautions section of the label to know what is required
- the job being done — for example, use more protection when handling concentrated pesticide or when mixing and loading a sprayer
- the type of application — enclosed space or air-blast sprayer applications made with open tractors require more equipment

All persons who work with pesticides need their own set of protective clothing and equipment. Consult the product label to find out what protective clothing is required.

For all pesticides, always wear:

- a water-repellent hat, such as a hard hat or waterproof rain hat
  - Sometimes the entire head and neck must be protected, for example, if applying pesticides in a greenhouse, applying dusty formulations or using an air-blast sprayer. In these situations, wear a hood or hat that protects ear canals. Do not wear baseball-style or other cloth hats, which absorb pesticides.
- long pants and a long-sleeved shirt or coveralls
  - Coveralls can be reusable or disposable. Reusable coveralls are normally cotton or polyester and should be tightly woven. Disposable coveralls should be designated for pesticide use.
  - Water-resistant coveralls are preferred because cotton, denim and cotton-polyester pants cling to the skin if they get wet, which increases the risk of dermal exposure.
- chemical-resistant gloves (unlined)
  - Use neoprene or nitrile gloves (PVC), unless the label states otherwise. Do not wear rubber gloves as many pesticides can break down the rubber material. Wear gloves under sleeves with the top cuffed.
- chemical-resistant boots (unlined)
  - Wear pant legs over boots to prevent pesticide from running down inside the boots.

Read the label. It will describe what extra protective clothing and equipment to wear.

For some pesticides, workers should also wear:

- goggles
  - Use safety goggles with indirect vents so that splashes do not enter the eye. Regular eyeglasses do not provide complete protection. Never wear contact lenses when handling pesticides.
- face shield
- chemical-resistant apron
- respirator
  - A respirator is a unit that covers the mouth and nose to prevent spray droplets, small particles and vapours from entering the lungs. A dust mask is not a substitute for a pesticide respirator. Respirators and replacement cartridges should be NIOSH/MSHA-approved. Use cartridges and pre-filters that protect against organic vapours. For more information, see the Grower Pesticide Safety Course manual, Ridgetown Campus, University of Guelph.

For fumigants:

- When you handle methyl bromide, do not wear gloves as they will trap gas next to the skin. Wear a full-face respirator with organic vapour canister or positive-pressure breathing apparatus. Some methyl bromide products require, by label, that self-contained breathing apparatus be worn at all times while using the product.

- When you handle aluminum phosphide, use cotton gloves and wear a NIOSH/MSHA-approved full-face mask respirator with an acid-gas canister.

Always check the label to find the appropriate safety equipment requirements.

When Working in Enclosed Areas

Canister respirators

Canister gas masks are effective for protection against certain harmful gases, vapours and spray particles. They are generally suitable for ventilated areas not subject to rapid change, but should never be used in

Table 2–3. Ontario Suppliers of Protective Clothing and Equipment

3-M Canada Inc.	Occupational Health and Environmental Safety P.O. Box 5757 London, ON N6A 4T1 *www.3m.ca*	Tel: 519-451-2500 Toll-free: 1-800-364-3577 Fax: 519-452-6720 Orders: 809-263-3489 OHS: 519-452-4600
Acklands Grainger	90 West Beaver Creek Road Richmond Hill, ON L4B 1E7 *www.acklandsgrainger.com*	Tel: 905-731-5516 Toll-free: 1-800-668-8989
Aearo Canada	6889 Rexwood Road Mississauga, ON L4V 1R2 *www.aearo.com*	Tel: 905-795-0700 Toll-free: 1-800-387-4304 Fax: 905-564-5250
DuPont Personal Protection	45 Dalkeith Drive Brantford, ON N3P 1M1 *www.dupont.ca*	Tel: 519-753-9306 Toll-free: 1-800-387-9326 Fax: 519-752-2161
Huron Tractor	305 Main Street North Exeter, ON N0M 1S3 *www.hurontractor.com*	Tel: 519-235-1115 Fax: 519-235-1939
HAMISCO	3392 Wonderland Road London, ON N6L 1A8 *www.hamisco.com*	Tel: 519-652-9800 Toll-free: 1-800-668-9800 Fax: 519-652-9661
Levitt-Safety (Eastern) Limited	2872 Bristol Circle Oakville, ON L6H 5T5 *www.levitt-safety.com*	Tel: 905-829-3299 Toll-free: 1-800-268-6196 Fax: 905-829-2919
Mitt & Robe Co.	751 Norfolk Street North Simcoe, ON N3Y 3R6 *www.mittrobe.ca*	Tel: 519-428-4050 Toll-free: 1-877-893-6565 Fax: 519-428-5142
MGS Horticultural Inc.	50 Hazelton Street Leamington, ON N8H 1B8 *www.mgshort.com*	Tel: 519-326-9037 Fax: 519-326-5861
MSA Canada Inc.	5535 Eglinton Ave. West Unit 222 Toronto, ON M9C 5K5 *www.msanet.com*	Tel: 416-620-4225 Toll-free: 1-800-267-0672 Fax: 416-620-9697
Plant Products Co. Ltd.	314 Orenda Road East Brampton, ON L6T 1G1 *www.plantprod.com*	Tel: 905-793-7000 Toll-free: 1-800-387-2449 Fax: 905-793-9157
Safety Express	4190 Sladeview Crescent Units 1 and 2 Mississauga, ON L5L 0A1 *www.safetyexpress.com*	Tel: 905-608-0111 Toll-free: 1-800-465-3898 Fax: 905-608-0091
Sun Parlour Greenhouse Growers Cooperative	230 Essex Road 31 Leamington, ON N8H 3W2 *www.sunparlourgrower.com*	Tel: 519-326-8681 Fax: 519-326-3413
The St. George Company (Suppliers of Kasco Helmets)	P.O. Box 430 20 Consolidated Drive Paris, ON N3L 3T5 *www.thestgeorgeco.com*	Tel: 519-442-2046 Toll-free: 1-800-461-4299 Fax: 519-442-7191

confined spaces where oxygen deficiency and high gas concentrations may occur.

Use canister respirators when the surrounding air contains low concentrations of toxic gases, vapours or particles derived from soil-drench, granular, dust or foliar spray applications. Pesticides applied in this manner usually have moderate to low toxicity.

Self-contained breathing apparatus

Air-purifying devices do not work in confined spaces where gas concentrations are unusually high. Substances that produce hydrogen cyanide, methyl bromide, chloropicrin or phosphine can produce high gas concentrations and oxygen deficiency as can volatile sprays, smoke generators and foggers that use highly toxic pesticides.

Use a self-contained breathing apparatus when applying highly toxic pesticides, especially in an enclosed space.

Other protective clothing

Wear other protective clothing in keeping with requirements listed on the pesticide label.

Safety equipment

Read the label for safety equipment recommendations and requirements. Protective clothing and equipment can be purchased from the suppliers listed in Table 2-3. *Ontario Suppliers of Protective Clothing and Equipment,* on page 12.

Care of Protective Clothing and Equipment

After spraying, clean all protective clothing and equipment.

Never let children, pets or livestock come in contact with contaminated clothing or equipment. Also ensure that they cannot come into contact with the puddles of water that result when cleaning equipment.

Wash gloves with soap and water and then leave them on to remove other protective clothing and equipment.

Always remove protective clothing and equipment outdoors. If a granular pesticide was used, shake the clothing outdoors in a safe place. Be sure to empty pockets and cuffs.

Dispose of clothing that has been contaminated by spills of highly toxic or concentrated pesticides. Place contaminated clothing in a plastic bag and take it to a landfill site.

Coveralls and other spray clothing must be washed separately from other clothes. They should be washed after each use. After laundering, place them in a plastic bag and keep them separate from other clothing.

Continue to wear gloves while washing protective equipment. It is best to wash equipment outdoors. If the work area does not have a cleanup area outside, designate specific buckets solely for equipment cleanup. Mark them and keep them in a designated place. Wash the inside and outside of goggles, hat, boots and any water-repellent clothing in warm soapy water, rinse well and let air-dry.

Respirators

Remove the cartridges and prefilters from the respirator.

Discard cartridges, canisters and filter pads at the interval set by the manufacturer or earlier if breathing becomes difficult, or a pesticide taste or odour is noticed.

Record the date the cartridge is first used.

Remove cartridges and filter pads from the face piece and store in clean, sealed plastic bags.

Wash the face piece in warm soapy water, rinse thoroughly and dry in a well-ventilated area. Air-drying prevents damage to the inlet and outlet valves.

Never use alcohol or other solvents for cleaning, as they will damage the rubber and plastic.

Rubber, vinyl or plastic boots and gloves

To avoid getting pesticide on hands, wash the outside of boots and gloves with detergent and water before taking them off.

After removing boots and gloves, wash them inside and out with detergent and water, rinse thoroughly and dry in a well-ventilated area.

How to wash clothes used for spraying

Never mix spray clothing with household laundry. All clothing used for spraying must be stored and washed separately from other clothing. Wash spray clothing after each use. Remember to use chemical-resistant gloves to handle pesticide-contaminated clothing.

Presoak clothing before washing. Use one of three methods:

- hose off garments outdoors
- soak in separate tub or pail
- use the prewash cycle in an automatic washer

Use hot water, the highest water level and the longest cycle with heavy-duty detergent. Wash as prescribed for heavily soiled clothing.

Wash clothing twice.

After washing, hang outside (preferably in bright sunlight) until completely dry. Do not use a clothes dryer.

Clean the washing machine. Run the washing machine through one complete cycle using only detergent and hot water (no clothing).

Personal hygiene

Always wash your hands before eating, drinking or smoking.

When finished for the day, take a bath or shower as soon as possible. The longer a pesticide remains on the skin, the greater the risk that it will be absorbed into the body.

Wash hair and under fingernails. Shower with a lot of soap and water.

Always change into clean clothes.

Wear clean work clothes every day. A small spill on the previous day's clothes may seem unimportant, but wearing the same clothing again without washing it prolongs exposure and increases risk.

Pesticide Application Procedures

Sprayers

Sprayers that can deliver sufficient volume for adequate coverage are satisfactory for applying emulsion-type insecticides.

If applying herbicides, always use a sprayer dedicated for that purpose. Do not use a sprayer to apply pesticides to crops if it has been previously used for herbicide applications.

Adequate agitation is essential when applying wettable powder formulations.

Pumps should be capable of delivering the flow and pressure required and compatible with materials sprayed.

Keep in mind that the higher the pressure, the greater the danger of drift.

Calibrate your sprayer at least twice during the season with each set of nozzles used. The wear on nozzles and other parts will alter the amount of spray delivered.

Check all nozzles for flow rate at least once a year. Replace nozzles when their output is 10% greater than rated output.

Sprayer calibration

Sprayer calibration is an important part of integrated pest management. Sprayer calibration:

- ensures that the proper amount of pesticide is applied
- ensures uniform pesticide application and coverage
- minimizes leftover tank mixtures, which can present disposal challenges

Handheld or backpack sprayer calibration

Many people use handheld spray guns or backpack sprayers for treating problem areas or spraying areas that were missed. To calibrate these sprayers:

- Measure an area that is 100 m^2, for example, 10 m × 10 m, or 25 m × 4 m.

- Fill the spray tank with water. Mark the level on a measuring stick. Pump to the pressure you will use during the pesticide application.
- Spray the water over the 100 m^2 area. Walk at a steady pace, taking care to apply it as evenly as possible, just as you would when applying pesticide.
- Measure the amount of water needed to refill the spray tank to the mark on the measuring stick. This amount will be the sprayer output per 100 m^2.

To convert the application rate of any pesticide to the amount required for a small area, follow this guide:

dry measure: 1 kg/ha = 10 gm/100 m^2
liquid measure: 100 L/ha = 1 L/100 m^2

For more information on calibration, see OMAFRA Publication 75, *Guide to Weed Control*. There is also a calibration calculator on the OMAFRA website at *www.ontario.ca/crops*.

3. Water, Growing Media and Crop Nutrition

Introduction

Living plants consist of 85–90% water with the remainder composed of organic matter and minerals. Photosynthesis occurs in the green leaves producing carbohydrates and ultimately organic matter. Water and minerals (plant nutrients) are taken up by the roots growing in soil or soilless substrate and transported within the plant through specialized tissue (the veins of the plant) called the xylem. Carbon dioxide from the air and light energy absorbed by chlorophyll are the drivers of the whole photosynthetic process. Most water taken up (≈90%) is lost through the leaves and into the air in a process called transpiration, primarily because of the vapour pressure difference between the internal leaf environment and the surrounding air. Small amounts of water (≈1%) are used for photosynthesis or as plant constituent (≈9%). Carbohydrates (sugars and starches) are produced by photosynthesis and distributed within the plant by conductive tissue called the phloem, generally in a downward direction.

Water

Water is one of the most important compounds for growing a crop, yet it is often the most neglected. Water serves as a medium in which chemical processes such as nutrient uptake and photosynthesis take place. It acts as a coolant through transpiration for both the crop and its environment. Both quantity and quality of water are critical for a good crop.

Uptake

Water uptake can be divided into active and passive uptake. Active uptake requires energy (from respiration in the roots) by increasing the nutrient concentration within the roots and creating suction on the water outside the roots through osmosis.

Passive uptake of water through the roots of the plant begins with water transpiration from the leaves, through openings called stomata. Water vapour moves from areas of high water vapour pressure in the leaves, through the stomata, to areas of lower pressure outside the plant. Under conditions of high humidity, the plant will lose less water vapour than when the humidity is lower, because there is a higher water vapour pressure outside the plant (resulting in a lower pressure difference between the inside of the leaf and the surrounding air). This process begins a chain reaction whereby water is drawn up through the xylem to replace what is lost through the leaves. Consequently, water in the soil is drawn in through the root hairs following the same gradient. Water uptake into the roots is also dependent on the moisture level and salt concentration in the soil. All three factors – relative humidity in the air, soil moisture and salt concentration in the soil solution – affect water uptake.

Quantity

Water requirements for a crop can vary between 0.1 and 7 L of water per square metre of greenhouse per day, of which 90% is required during daylight hours. This varies according to plant species, plant size, relative humidity, solar radiation, temperature/heating and rate of ventilation. When sizing irrigation equipment (lines, pumps, nozzles), it is recommended that a minimum of 1 L/m^2/hour be used as a base requirement for capacity sizing of the irrigation lines and system. The total annual water requirement for a year-round greenhouse operation with a high leaf area index (e.g. vegetables) in a recirculating system exceeds the Ontario annual precipitation of approximately 75 cm by 25%–35%. This means that rainwater collected from the greenhouse roof alone will not fulfill the annual requirements of a crop. Water is particularly critical during the summer. Greenhouse operations using a large daily volume obtained from surface or groundwater sources must comply with Ministry of the Environment regulations (Permit to Take Water) regarding the usage.

Permit to Take Water
www.ene.gov.on.ca/envision/water/pttw.htm

Permit to take water

The *Ontario Water Resources Act* (OWRA) and the Water Taking and Transfer Regulation (O.Reg.387/04) govern the taking of water in Ontario.

Section 34 of the OWRA requires anyone taking more than a total of 50,000 L of water in a day, from a lake, stream, river or groundwater source (including spring-fed ponds), to obtain a permit from the Ministry of the Environment (MOE) to take water. All permit holders are required to collect and record the volume of water taken daily and report these data annually to the MOE.

Water conservation is an important part of the MOE's Permit to Take Water program.

Conservation measures being proposed or taken must be documented when making an application.

For further information, refer to the Permit to Take Water Manual, the Guide to the Permit to Take Water Application Form and other related fact sheets on-line at *www.ene.gov.on.ca/envision/water/pttw.htm*.

Managing water use

Efficient use of water as a resource should be a key best management objective of every greenhouse operation. Closed or recirculating nutrient systems are inherently the most efficient, but are not suitable or cost effective for all cropping systems. For growers using open irrigation systems, there are a number of approaches to consider. For example, converting to low volume drip emitters for potted flowering crops and to low volume drip tape for soil-grown cut flowers are relatively low-cost considerations to reduce the amount of water and fertilizer used, and potentially leached, from the root zone of the crop. Greater integration of the growing environment (light, temperature and humidity) with respect to crop and crop age can also reduce water and fertilizer usage. Consideration should be given to directing tile drain leachate into an irrigation pond, an artificial wetland or vegetative filter strip before discharging to the environment. Both federal and provincial legislation protect watercourses and aquatic organisms from harmful discharges.

Quality

In addition to having a plentiful and reliable supply of water, the quality must also meet certain criteria, the most important of which are:

- the concentration of suspended particulates, which can affect irrigation equipment or residue on the foliage with overhead watering
- the amount of dissolved chemicals/elements, which can impact plant growth and nutrition

It is the latter (the amount of dissolved chemicals) that causes growers the most concern. The specific requirements for water quality depend on several factors:

- The type of growing/irrigation system to be used – it can be a once-through or recirculating top irrigation system (soil or substrate), a recirculating system (sub-irrigation system for potted plants), or a nutrient film technique.
- Water quality standards must be higher for a recirculating system, as ions like sodium or chloride will accumulate in the solution. There is the increased potential for spread of root diseases when recirculating irrigation water.
- Good drainage to remove excess water in case the need for leaching arises.
- The type of crops to be grown and their specific needs for, or sensitivities to particular elements such as boron, fluoride, zinc, etc.

In situations where crops are being irrigated from the top (overhead) with no recirculation, a simple water analysis to determine water quality will suffice. This analysis includes electrical conductivity (EC), hydrogen ion (pH), sodium (Na^+), chloride (Cl^-), and sulphate (SO_4^{2-}) concentration. For sub-irrigation or in recirculating systems, a complete water analysis including bicarbonates (HCO_3^-) and micronutrients such as iron (Fe^{2+}/Fe^{3+}), boron (B), zinc (Zn^{2+}), manganese (Mn^{2+}) and copper (Cu^{2+}) is recommended.

Electrical Conductivity (EC)

The Electrical Conductivity (EC) is a measurement of the total concentration of ions (or total ionic charge) in the solution. The total ionic charge is measured by an EC meter, and is often referred to as the total soluble salts. A high number of ionic charges results in a high EC. The EC measures the conductivity of a solution by means of two electrodes, each 1 cm^2 in size and 1 cm apart. It is expressed in millimhos/cm (mmho/cm) or milli-Siemens/cm (mS/cm or dS/m) at the standard temperature of 25°C. Another method of referring to soluble salts is by the ionic concentration in equivalent weight per litre (eq/L or meq/L), which represents the amount of charge provided by all ions in solution.

To convert between eq/L and mS/cm*:
- 1 meq/L ≈ 0.055 mS/cm ≈ 55μS/cm
- 1 mS/cm = 1,000 μS/cm ≈18.2 meq/L

* The 'm' represents milli (0.001 or 1 part per thousand) and the μ represents micro (0.000001 or 1 part per million).

Remember that an EC meter does not measure the concentration of specific ions but rather the total sum of all ionic charges. The higher the value, the higher the concentration of ions in solution, which makes it more difficult for plants to absorb water from this solution due to the increased osmotic suction. The EC meter should be calibrated on a regular basis with a standard solution that has a known EC. For example, 0.01 M (molar) potassium chloride (KCl), made by dissolving 0.74 g KCl in 1 L water, has an EC of 1.4 mS/cm at 25°C. With repeated use of the meter, the EC reading becomes lower as the electrodes oxidize. Clean the electrodes by placing them in an acid solution (pH 1.0–2.0) overnight. If the EC meter is not temperature-corrected to 25°C, increase the measured values by 2% for each 1°C less than 25°C.

A general quality classification for water is given in Table 3-1. *Classification of Water Quality Based on Electrical Conductivity (EC) and Certain Specifications*, on this page. Note that all conditions must be met in order to place a sample in a certain class.

Table 3-1. Classification of Water Quality Based on Electrical Conductivity (EC) and Certain Specifications

Class	E.C. (mS/cm)	Sodium (Na$^+$) (ppm)	Chlorides (Cl$^-$) (ppm)	Sulphates (SO$_4^{2-}$) (ppm)
1	<0.5	<30	<50	<100
2	0.5–1.0	30–60	50–100	100–200
3	1.0–1.5	60–90	100–150	200–300

Source: The information in this table is historical data developed over time by Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) greenhouse specialists.

Water quality of Class 1 is good for all irrigation purposes. Most water obtained from Lakes Erie and Ontario falls within this category. Water in Class 2 should only be used in substrate and soil culture where adequate leaching can take place. It is not suitable for a nutrient film technique and salt-sensitive crops grown in sub-irrigation systems. Class 3 is not recommended for salt-sensitive crops (e.g. primula, African violet, gloxinia), or crops grown in a limited root volume or recirculating systems. If the salt level exceeds 1.5 mS/cm, it is considered marginally suitable for greenhouse irrigation. In some cases crops can be grown, but yields may be reduced as a result. The toxic concentration for sodium (Na$^+$) is lower than that for chlorides (Cl$^-$) due to the tendency of sodium to be absorbed in soil or humus particles and accumulate in the soil/substrate. It may interfere with the uptake of potassium, calcium and magnesium. Chlorides have fewer tendencies to accumulate in soil/substrate due to their negative charge. Some crops (e.g. cucumber, azalea, lilies) are chloride sensitive. Note that for most areas in Ontario, sodium levels are low in well water, while sulphates can be relatively high due to the presence of gypsum in the aquifers. Most crops do not require more than 100 ppm of sulphates (33 ppm elemental sulphur) to meet their nutritional requirement for sulphur.

Why measure media or media/solution EC?

Though the EC measurement does not indicate the presence or quantity of nutrients, it does provide an overall level of the nutrient status of the solution. A high EC indicates there are many dissolved ions in solution, which makes it difficult for the plant roots to take up water. In severe cases of high EC, roots may lose water, which leads to root damage or death. This generally occurs when there is insufficient leaching, plants are over fertilized or the irrigation water is of poor quality (high EC). Foliage may be dark-green and small, and plants may wilt during the brightest or hottest part of the day even though the media is not dry. Most importantly, plant roots may be brown in colour with little or no new active white roots present.

A low EC indicates that there are few dissolved ions in solution and it is easier for roots to take up water. The plants will usually be more lush and may actually be slightly under-fertilized since there are not as many nutrients available. However, root growth will be encouraged. Low EC often leads to a deficiency of one of the macro-elements (nitrogen, phosphorus, potassium, calcium, magnesium or sulphur).

How to measure EC of the growing medium

There are four primary ways to determine EC in a substrate sample:

- saturated medium extraction (SME) method
- Spurway (1 soil:2 water) dilution method
- pour-through method
- squeeze method

The SME and Spurway method involve removing a sample of substrate from the root zone and taking measurements of the filtrate. With the SME, sufficient water is added to the substrate so it becomes saturated, while the Spurway technique mixes one volume of soil with two volumes of water. These are the most commonly used techniques in an analytical laboratory. Across North America, the SME is the most common greenhouse media extraction procedure used by university and private laboratories. The EC using SME is usually approximately 2.5 times greater than that measured by the 1:2 Spurway technique.

The pour-through method is accomplished by pouring distilled or deionized water into the media from the top of the pot and collecting the first 50 mL of the leachate for EC and pH readings. This method is rapid and very useful for in-house monitoring, but the water has to be poured evenly and consistently over the soil surface. In addition, high values can be found in some older (especially sub-irrigated) pots due to high salts at the top of the growing medium, while the root zone may actually have lower EC values. When using this method be sure the media is moist to ensure accurate reading.

Another option for in-house monitoring is the squeeze method where plants are removed from the pot, and the lower half of the root ball is squeezed to extract the root-zone nutrient solution. This gives a fairly good representation of the actual level *in situ* of the soil solution in contact with active roots. This technique is widely used for monitoring media EC in plug seedling trays. Because of the small sample solution extracted, a special EC meter, which uses only 1–2 drops of solution, must be used. Media must be quite moist to be able to extract solution from the media.

Interpretation of EC data

The nutrient demand of a crop depends on the crop development and can be divided into three stages: a low demand during seed germination or rooting of cuttings, a high demand during the very active vegetative stage of crop growth, and a lower demand as the plants reach maturity. As a general rule, shelf life is improved by lowering the nutrient levels (and reactivating the root system) towards the end of the crop (e.g. chrysanthemum and poinsettia); however, some crops such as Easter lily benefit from continued fertilization right up until shipping.

Table 3-2. *Relative EC Requirements of Actively Growing Greenhouse Crops Using the Saturated Medium Extraction (SME) and Pour-through Methods,* on page 21, provides suggested EC levels for the actively growing stages of various potted crops using two sampling techniques. For the initial and final growth stages, lower the EC by about 1.0 mS/cm. Sample five pots per representative area per week, calculate the average and record the results.

- If the EC is too low, raise it by increasing the rate of fertilization.

- If the EC is too high, lower it by leaching with fresh water. For top irrigated crops add water from the top. Apply sufficient water to saturate the growing media to increase the solubility of excess salts. Wait 1–2 hours and apply sufficient fresh water to push the high EC solution down and out of the pot. A form of leaching can also be used for sub-irrigated crops, but rather than flushing the salts out of the media, the salts are moved into the upper zone of the media where no active roots exist. It is important to determine if the high salts are only in the upper part of the growing medium (which is normal in sub-irrigated crops and does not affect the root zone), or if they are also high in the active root zone. If the root zone has a high EC, sub-irrigating with clear water is appropriate, as the salts are forced upwards.

Crops grown during low light conditions in the autumn and winter require a higher EC than during the summer, because reduced transpiration during this time of the year results in less water (and fertilizer) being taken up. In the summer, because of high transpiration and increased water uptake, it is important to compensate by lowering the EC of the nutrient solution (fertilizer solution) being applied to the crop. In the summer, the EC of the fertilizer solution being applied to sub-irrigated crops should be reduced by 30–40% compared to winter.

Table 3-2. Relative EC Requirements of Actively Growing Greenhouse Crops Using the Saturated Medium Extraction (SME) and Pour-through Methods

Nutrient Requirements	SME (mS/ cm)	Pour-through (mS/cm)	Crops
Low	0.75–2.0	1.0–2.6	African violet, azalea, begonia, calceolaria, calla, cineraria, cyclamen, gerbera, gloxinia, impatiens, orchid, primula, streptocarpus
Medium	1.5–3.0	2.0–3.5	Schlumbergera, clerodendrum, dahlia, exacum, zonal geranium, hibiscus, kalanchoe, rose, calibrachoa
High	2.0–3.5	2.6–4.6	Chrysanthemum, poinsettia, lily, geranium

Source: The information in this table is historical data developed over time by Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) greenhouse specialists.

pH and its Role

pH is the inverse measure (or a negative logarithm) of the concentration of hydrogen ions (H^+) in solution. A high number of H^+ ions results in a low pH, while a low number of H^+ gives a high pH. pH is measured on a scale of 1–14, where a pH less than (<) 7.0 is acidic, more than (>) 7.0 is basic, and 7.0 is considered neutral. The higher or lower the pH, the more strongly basic or acidic the solution. Each unit in the pH scale represents a change in the concentration of H^+ by a factor of 10.

Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acids or hydrogen ions. Alkalinity is connected to pH because it establishes the buffering capacity of water; it defines how resistant the water is to a change in pH. Under most Ontario conditions, the ion having the greatest effect on alkalinity is bicarbonate. In Ontario, it is not unusual to have water with more than 200 ppm of bicarbonates, which originates from the underlying limestone (calcium and magnesium carbonate) base. In this case, the high concentration of bicarbonates neutralizes the hydrogen ions, resulting in a low concentration of H^+ and therefore a high pH. It is important to note that there is a general correlation between pH and bicarbonate, but this relationship is not specific. Therefore, the amount of bicarbonates present in the water source must be known in order to determine the amount of acid needed to neutralize the pH. When you want to know how much acid to use to neutralize the pH, you must know the amount of bicarbonates.

Greenhouse testing laboratories report alkalinity in different ways. Ontario laboratories report the ppm of bicarbonate present in the water while others report it in other ways with mg/L $CaCO_3$ of alkalinity or millequivalents (meq) alkalinity being most common. The relationship between this terminology is as follows:

- 61 ppm bicarbonate = 50 ppm alkalinity = 1 meq alkalinity

How does the bicarbonate level or alkalinity affect the growing medium pH?

When the bicarbonate concentration or alkalinity is high, pH will rise quickly when high volumes of water are applied through top irrigation with high leaching rates or through sub-irrigation with no leaching potential. This is because the typical bicarbonate level in Ontario well or surface water has much more buffering capacity than the acidity or basicity of the fertilizers being used to grow the crops.

How to measure pH

There are three main methods of measuring pH in solution:

- Litmus paper, which is the least expensive (but also the least accurate method), involves dipping the paper into the solution and comparing the colour change in the paper to established colour codes for different pH ranges.

- pH pens, which are reasonably priced, quite accurate and easy to carry around in the greenhouse. They are simply dipped into the solution to provide a digital readout of the pH.

- Electrode-type pH meters, which are the most accurate for measuring pH, are also the most expensive and require the most maintenance. Placing the pH probe directly into the solution until the reading stabilizes gives a quick reading. Many of the better pH meters have temperature compensation, but the temperature dependence is small (usually within 0.1–0.3 units). Rinse the probe between samples. Calibration is very important. The probes are not as stable as the probes of EC meters. Calibrate probes at least once per week using standard pH solutions of 4.0 and 7.0. Keep probes clean and stored in solution, and replace more frequently than EC probes.

Check the pH of the substrate using the slurry or solution collected for measuring EC. In this case, use distilled water as many water sources have pH buffering compounds (e.g. bicarbonates) that can affect the pH.

Why measure pH?

Although hydrogen ions are not considered one of the nutrient elements, pH does influence the solubility and thus the availability of other nutrients (especially micronutrients). For instance, most positive ions (cations) such as iron, manganese and calcium, as well as phosphates, are more soluble (and therefore more available to the plant) at a lower pH. Conversely, at higher pH, such ions can be tied up in unavailable forms. Molybdenum on the other hand, is more available at a higher pH. The pH also directly influences the colonization of certain pathogens in the soil that may be harmful to plants.

Different crops have different sensitivities to pH based on their sensitivities to some of these micronutrients (or lack thereof). For example, pH <5.5 can result in the accumulation and toxicity of nutrients such as manganese and iron in marigold, geranium and zygocactus. In other plants, such as azalea and hydrangea, a low pH is required to ensure maximum uptake of iron and aluminum, which is essential for proper leaf and bloom colour. A pH of 5.5–6.5 is considered optimal for most crops grown in soilless mixes with more than 50% organic matter. Table 3-3. *Optimal pH Range for Various Crops,* on this page, lists crops with more specific optimal pH ranges.

Table 3–3. Optimal pH Range for Various Crops

Crop	Optimal Range
Marigold, geranium, celosia, Easter lily	6.0–6.6 (+/–0.2)
Pansy, petunia, snapdragon, vinca, salvia, blue hydrangea, calibrachoa, petunia, bacopa	5.4–5.8
Azalea	4.8–5.4

Source: The information in this table is historical data developed over time by Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) greenhouse specialists.

Other factors to consider include:

- It is desirable for crops sensitive to low pH, such as geranium and marigold, to have slightly higher pH.

- Petunia, calibrachoa, bacopa, scaevola are prone to iron deficiency and should be grown at a pH below 5.8.

- Crops such as pot chrysanthemum, which tend to force the pH to rise over time, should have a lower pH early in the crop.

- The stage of crop growth (age). At flowering, pH is often not as critical as it is earlier in the crop.

- The fertilizers being used also affect the pH of both the nutrient solution and media. It is important to know whether the complete fertilizer being used is basic or acidic in reaction. This is stated on the fertilizer packaging as the potential acidity by the number of kilograms of calcitic limestone per tonne of fertilizer. Likewise, if the fertilizer is basic in reaction, then it is stated as the potential basicity.

Because of the bicarbonate content of most well and surface waters in Ontario, most growers now adjust the pH of their irrigation water using either phosphoric, nitric or sulphuric acid to maintain the pH of the crop growing medium at pH 6.2 or lower. Because many growers are required to collect rainwater, blending of surface water with rain water is usually recommended to better manage fertilizer solution pH.

Adjusting the pH

Irrigation water

For many smaller operations, injecting acid through the fertilizer injector is the method of choice. Ensure that the injector is designed to handle acids. For other growers, installation of in-line pH probes controlling an acid pump is the method of choice. Both methods are effective. Required rates of acid are shown in Table 3-4. *Volume of Acid Required to Neutralize 61 ppm* HCO_3^- *(1 mmol/L or 1meq/L) per 100,000 L of Water,* on this page.

It is recommended to leave about 60 ppm bicarbonates in the irrigation water as both a buffer and also to provide a margin of error against small changes in water makeup and dosing rates. Therefore, if the initial level of bicarbonates is 240 ppm, approximately 180 ppm should be neutralized; in this case, three times as much acid as is indicated in the table would be needed.

When 1 mmol/L or meq/L of bicarbonate is neutralized with different acids, the following nutrients are added to the solution:

- if using nitric acid, 14 ppm nitrogen (in nitrate form)
- if using phosphoric acid, 31 ppm of phosphorus (as 71 ppm P_2O_5)
- if using sulphuric acid, 16 ppm sulphur (as 48 ppm sulphates)

Table 3–4. Volume of Acid Required to Neutralize 61 ppm HCO_3^- (1 mmol/L) per 100,000 L of Water

Acid	Spec. Gravity (kg/ L)	Volume of Acid (L)
Phosphoric (85%)	1.7	6.8
Nitric (67%)	1.5	6.6
Sulphuric (93%)	1.8	2.8

Media

If the pH is too low, consider one or more of the following steps but keep in mind that it is difficult to adjust the pH upward.

For soilless mixes

- Discontinue acidifying water supply.
- Shift to a basic-reaction fertilizer (high in nitrate nitrogen).
- Use potassium bicarbonate (100–200 kg/1,000 L) of stock at 1:100 dilution, with an EC in the final solution of approximately 1.5–2.0 mS/cm.
- If limestone is used, the amount to add depends on the type and ratio of the ingredients. Sphagnum peat moss (pH 3.5–4.5) and bark (pH 4.0) are acidic. The amount of limestone needed to neutralize sphagnum moss from a pH 3.5 to a pH 5.5 is approximately 6–7 kg/m^3 of loose peat moss. Alkaline materials are often the baked-clay types, such as Haydite and Crackpot or sand. Adding clay additives with a high pH should reduce the amount of limestone needed. Check the pH after preparation but before planting. The pH of newly prepared moist media will continue to rise for about 10 days.

For soil beds

- To increase the pH by 1 unit, use 4.8 kg limestone per 100 m^2.
- For a soil with higher clay content or a higher organic matter content, increase the recommended amount by approximately 25%.
- Two to three weeks after application, check the soil pH to see if the desired pH level has been attained. Note that the finer the limestone, the quicker its reaction with the soil.
- The rate of pH change is also affected by temperature, moisture and aeration conditions of the soil. Changes will occur most rapidly when soils or soilless media are warm, moist and well-aerated.
- The use of hydrated lime in greenhouses has some severe drawbacks, as it reacts very quickly and thoroughly. Proper distribution of the material throughout the soil mixture is difficult and consequently, the use of this material is very limited. However, it is often used as a portion of the total limestone demand for soilless media in order to achieve a quick change in the pH, so that the media can be used for planting.

A media pH that is too high can be difficult to lower, but one or more of the following steps will help:

- Increase the acidity of the irrigation water. Usually it is harmless to lower the pH of the nutrient solution to 5.2–5.4, while maintaining 30–60 ppm of bicarbonate (see above). The goal is providing an acidic solution around the roots to allow for uptake of micronutrients until the nutrient solution is buffered up in pH.

- Discontinue using basic-reacting fertilizers such as calcium nitrate.

- Use more ammonium-based fertilizers.

- Drench with iron sulphate at 5 kg/1,000 L of water. Be sure to lightly wash the foliage immediately afterward to avoid burning.

- Use elemental sulphur at 15 kg /1,000 L of water. This treatment requires 3–4 weeks to be effective.

See also Table 3-5. *Adjusting pH for Soil Beds.*

Table 3–5. Adjusting pH for Soil Beds

Materials	kg/100 m² to Lower pH 0.5–1 Unit*	Rate of pH Change
Finely ground sulphur	2.5	Slow
Aluminum sulphate	15	Rapid
Iron sulphate	15	Moderate

* Rates are for light to medium soils. For heavier soils with more organic matter, increase rate by one-third. The rates per m³ of potting soils are one-half of the above recommended rates.

Soilless Growing Media

Commercial growers have replaced soil-based mixes with soilless mixes. Whether the mix is used for plant growing, propagation, container growing, bench crops or even cut flowers, there has been a gradual reduction in the use of actual soil and an increase in the use of artificial ingredients. Soilless mixes are available already prepared in bags or bales, in bulk or as separate ingredients that can be blended together by the grower.

Why use soilless mixes?

Soilless mixes offer several advantages over a conventional soil mix:

- There is uniformity and consistency in each batch.

- Most are considered to be essentially free of diseases and insects, thereby reducing the need for costly pasteurization. They are generally considered free of weed seeds as well.

- There is less likelihood of contamination from herbicide residues, which can occur with mixes containing field soil.

- The ingredients of a soilless mix are readily available and most are much lighter than soil.

- Soilless mixes have greater pore space and higher water-holding capacity than soil-based mixes.

Functions of a good growing medium

A growing medium should perform four basic functions:

- provide an anchor system for the plant roots
- store water for absorption by plant roots
- provide a buffer for nutrients absorbed by the roots
- provide oxygen (air space) for root respiration

Common ingredients

Sphagnum peat moss

This is one of the most widely used materials, due to its physical characteristics and price. Sphagnum moss is a primitive plant that grows in bogs. While the upper part of the plant continues to grow, the bottom part dies, decomposing into peat. The moss leaves consist of living cells that may or may not contain chlorophyll, as well as dead "sphagnum" cells, which contain water and air. The dead sphagnum cells are unique in that they can absorb and conduct water. These cells have lignified walls that prevent their collapse when drying out. Water in these cells is absorbed by capillary action. Because the leaf and stem cells are surface active and are generally negatively charged, they can adsorb nutrients (e.g. positive ions) in a similar way to clay particles. Nutrients can also be absorbed in the sphagnum cells as dissolved ions in water.

A sphagnum peat bog has a top, middle and bottom. Because of the way sphagnum grows, the older mosses will be at the bottom and are the most decomposed. They are also the darkest in colour and finest in particle size. The top layers are more yellowish and coarser in structure. The coarser the peat, the lower the bulk density, the greater the air space, the lower the water-holding capacity (by volume), and as a result, the better the quality.

The method of peat moss harvesting plays an important role in particle size distribution. Peat is harvested in two ways: the vacuum method and the block cutting procedure. Vacuum harvesting involves loosening the surface, air drying and vacuuming the top surface of the bog. Block harvesting involves digging the peat in chunks and letting them dry over winter. The following spring, the chunks are loosened and packaged. Block-harvested peat is coarser than vacuum-harvested and is usually considered the best quality, but is also more expensive.

Cation exchange capacity (CEC) indicates how many cations can be adsorbed per unit weight and how their supply to plants will be regulated (buffered). With its high CEC, peat moss is well suited as a nutrient reserve and buffering agent. Pure peat moss, however, contains very few nutrients as determined by the electrical conductivity of the saturated medium (EC<0.5 mS/cm).

Due to its naturally low pH (3.5–4.5), peat moss is considered to be free of active pathogenic diseases, although dormant pathogenic spores or weed seeds may be present.

The low cost on a volume basis makes peat moss one of the more desirable mix ingredients. Normally, commercial and grower-made mixes today consist of 50–100% sphagnum peat moss. The sphagnum peat mosses available in Ontario are generally sold in a compressed form and will expand by 40–60%, depending on compression level.

Vermiculite

This is a mica-like material that has been expanded under high temperature (900°C). This material can be compared to clay particles, except that it has lost its swelling and shrinkage capabilities. It has a high cation exchange capacity (CEC), similar to peat moss on a weight basis, and contains considerable quantities of potassium and magnesium ions. It improves air porosity, provides structure to the medium (less shrinkage) and makes rewetting of a mix easier. Water can also be absorbed internally between the platelets. Acidity is near neutral, and bulk density is 80–100 kg/m^3. Three grades are normally available – coarse, fine and regular. It is mined in South Africa, the United States, China and Brazil.

Perlite

This is an aluminum-silicate of volcanic origin that has been heated to approximately 1,000°C. It is similar to popcorn as it consists of a number of closed, air-filled cells. Water is absorbed primarily on the outer surface and to a lesser degree within the particle. This inert material is primarily added to the mix to improve aeration and drainage, as well as structural stability. The pH is approximately 7.0, and the CEC is negligible. Its bulk density is similar to that of vermiculite or peat moss, at approximately 100 kg/m^3.

Coir

Coir is the coarse fibre pith produced as byproduct when the long lignin fibres are extracted from the fibrous outer husk of the coconut fruit. These fibres are typically washed with fresh water to remove the excess sodium and chloride ions prior to processing for horticultural uses. It has a high water holding capacity, 8–9 times its dry weight. It has excellent wetting properties and high cation exchange capacity. The pH is typically 5.7–6.5. Prior to planting, growers should complete an EC sampling of each shipment to ensure that the coir was adequately washed to remove potentially high sodium and chloride levels. Coir is available as 1 L compressed bricks that will expand to 8–9 L of fluffed up material, as chunks, and as compressed 1 m slabs sleeved with plastic for greenhouse vegetable production. Compressed bricks that fail to expand properly when wetted should be discarded. Currently, coir is being used for the production of long-term cut flower crops, such as gerbera and roses grown in containers or troughs.

Rockwool

This product is manufactured from basalt and limestone by spinning the molten rock. There are two forms available – the bonded product and the granulated material. The base material is sterile and does not contain any CEC or an appreciable level of soluble salts. The bonded product is cut into slabs 15 or 20 cm wide, 7.5–10 cm thick, and 90–200 cm long. It can be purchased with or without a plastic sleeve. Slabs contain a binder for stability and a wetting agent to facilitate water absorption and distribution. The granulated material comes in three sizes (fine, medium and coarse) and does not contain any binder and/or wetting agent. Granulated rockwool is added to a mix to increase pore space and water-holding capacity, as well as for easier rewetting if the medium is allowed to dry out. Rockwool is currently used for the production of a few long-term cut flower crops, such as roses and gerbera, and greenhouse vegetable crops.

Rockwool can also be manufactured from steel slag. This material, often referred to as mineral wool, generally has a relatively high pH (7–8) and higher levels of micronutrients compared to rockwool.

Polystyrene chips

This is a waste product created from polystyrene bead boards. The material is inert, with negligible CEC and near-neutral pH. Its role in a media is similar to perlite, except that there is no surface absorption of water. Bulk density is 25 kg/m^3, and it cannot be pasteurized due to shrinkage. It has a tendency to float to the surface of the pot and can be a nuisance with recirculating sub-irrigation systems. Soil mix uniformity can be a concern because of its tendency to separate from the rest of the mixture.

Turface®

This is a baked clay with neutral reaction (pH 7.0). Because the bulk density is 750 kg/m^3, and the CEC is high for regular grade, the material is used to increase the weight and the buffering capabilities of the mix. The CEC is comparable to vermiculite.

Haydite®

This is a shale expanded by treating to 1200°C. Bulk density is approximately 800 kg/m^3, depending on size and grade. It has a high pH (8.5–9.5) and can be obtained in several grades according to particle size. The neutralizing capacity of this material has to be considered when used in appreciable quantities.

Gro-Bark®

Composted barks may suppress toxic substances and plant pathogens. Hardwood barks are generally composted for three months, while softwood barks take approximately one and a half months to compost. Nitrogen is generally added at 1 kg or 0.5 kg/m^3 for hardwood and softwood bark, respectively, before composting. Gro-Bark®, a commercially available product, is a blend of aged pine bark and sawdust that has been naturally composted for 10–40 years. It ranges in pH from 4.5–6.5 and is low in salts. Available in bulk only, it is often used as bedding in walkways, as an amendment for containerized nursery material, or as a substitute for peat moss.

Grow-Rich®

Grow-Rich® is a composted material produced from paper mill sludge and other organic materials (animal manures, sawdust and corncobs). The bulk density is approximately 400 kg/m^3, while typical particle size ranges from 3–6 mm. The pH is between 5.5–6.5, and soluble salts are near 1.5–2.0 mS/cm, using the SME method. As a consequence, the final potting mix should not contain more than 25% of this material.

Worm castings

Worm castings are a byproduct of worm raising. They are high in organic content and stable in structure. The pH is 6.0–7.5, while soluble salts are between 1.0–1.5 mS/cm. Bulk density is approximately 200 kg/m^3. It should be used sparingly in a mix (less than 25% of the volume) to provide structural stability and more pore space to the media. It is somewhat hydrophobic in nature, may contain weed seeds and is quite expensive.

Sand

Although technically a type of soil, sand is quite often incorporated into soilless mixes to provide weight. It is about 15 times heavier than the other major components (peat, perlite and vermiculite). Drawbacks with sand include:

- its grinding action on the other ingredients if mixed too long, causing a reduction in air space

- its potential for containing plant pathogens, therefore requiring pasteurization

However, sand (similar to soil) improves wettability of the mix. Depending on its source in Ontario, sand often has a high pH (approximately 8.5), indicating the presence of free calcium carbonates. Consider its neutralizing capacity when using.

Physical characteristics of a soilless mix

A soilless (or soil) mix has three major components – air, solids and water. The air space is needed to provide oxygen for root respiration and to allow nitrification and some microbial activity. The air space in a mix complements the water portion, since air replaces the water absorbed by the plant roots. The air/water ratio in a mix is determined by the particle size of the solids. After a coarse mix is watered, air will enter the mix more quickly than in finer mixes, but may not be distributed uniformly. Therefore, a coarse mix has relatively more air and less water-filled pore space than a fine one. A lack of air space can be a problem when using a fine-textured mix during the lower light periods of the year. Another factor that affects the air/water ratio is the height of the pot; the taller the pot, the greater the air/water ratio, especially in the top of the pot.

After watering, a soilless mix may have up to 75% of the total space filled by water, with the remainder taken up by solids (5–10%) and air (15–20%). In a soil mix, solids compose 50% of the space, with the balance divided between air and water. This basic difference between a soil and a soilless mix therefore necessitates a change in crop management. The bulk density of most soilless mixes is approximately 100–200 kg/m^3. Shrinkage of the mix is of some concern due to the changing physical properties, but also due to the volume of the medium required for a given pot size. Peat moss and rockwool will both shrink. The addition of structural components such as perlite or vermiculite, or compressing the mix when filling the pots, helps to alleviate medium shrinkage.

See also Table 3-6. *Example of a Soilless Mix with Amendments,* on this page.

Preparing a soilless mix

There are several factors to consider when preparing a soilless mix:

- water-holding capacity
- air porosity
- nutrient availability
- buffering capacity
- weight
- price

Table 3–6. Example of a Soilless Mix with Amendments

Ingredients	Percent (by volume)
Sphagnum peat moss	50–60%
Vermiculite, perlite, polystyrene, bark, granulated rockwool	20–40%
Turface®, Haydite®, sand	10–20%
Amendments	Rate/m^3 of mix
Limestone (fine grade, dolomitic)	3.5 kg
Superphosphate	1.5 kg
Potassium nitrate (12-0-44) or ammonium nitrate (34-0-0)	1.0/0.4 kg
Trace elements	0.25–0.5 kg
Wetting agent	100 mL

Due to its excellent growing properties, the major component in most soilless mixes is sphagnum peat moss. The quality of the peat moss is important as it is the principal ingredient. A coarse peat provides more natural air space and could be used at a higher percentage in the mix. A finer mix, with less air space, should constitute less of the final mix. For aeration purposes and to give structure to the mix (with less shrinkage), use one or a combination of the following ingredients: vermiculite, perlite, granulated rockwool or polystyrene chips. Vermiculite and rockwool are excellent materials, as they increase water-holding capacity and have good rewetting characteristics. The third ingredient (Turface®, Haydite® or sand) is added for weight, buffering capacity and/or pore space.

Add limestone (3.5 kg/m^3 of mix) to bring the pH of the mixture to an acceptable level (based on a mix containing 50% peat moss). The amount of limestone indicated does not take into account any neutralizing effects from the other ingredients (e.g. Haydite®, sand) or the acidifying effect of some fertilizers (e.g. ammonium nitrate). It may take one week after mix preparation and initial wetting before the pH is stabilized.

When using calcitic limestone, supply magnesium in the form of Epsom salts (0.5 kg/m^3). Add superphosphate for phosphorus, sulphur and calcium. If nitrogen and/or potassium are also added, use potassium nitrate (12-0-44) at 0.5–1.0 kg/m^3, or ammonium nitrate (34-0-0) at 0.3–0.5 kg/m^3. The nitrogen addition will amount to approximately 0.25–0.50 g nitrogen per 15 cm pot. In some instances, calcium nitrate may be used as the nitrogen source at 0.5 kg/m^3. Use Nutritrace or a similar micro-element mix to add trace elements of iron (Fe), copper (Cu), boron (B), zinc (Zn) and manganese (Mn). As a wetting agent, a non-ionic reagent such as Aqua-Grow® or Agral-90 is suitable. Dissolve the wetting agent in warm water and spray over the mix for uniform distribution. Sometimes a combination of trace elements and wetting agent is available in granular form. For the purpose of convenience, many growers have the amendments premixed by their fertilizer supplier. Most ingredients can be mixed when dry. Screw-turn and tumbler-type mechanical mixers can be used, but prevent pulverization of components by minimizing mixing time. Add water when the ingredients are being mixed to prevent dust and promote stable particles.

Chemical characteristics of mixes

After preparing a mix, always check the total soluble salts (EC) and pH. The EC gives an indication of the nutrient status by measuring the conductivity of the solution, while the pH plays a major role in determining the nutrient availability (see *Electrical Conductivity (EC)*, on page 19). The optimal pH for organic soilless mixes is approximately 5.5 (±0.5). This contrasts with the recommendation of pH 6.5 for soil mixes. In the peat-like mixes, a high pH (over 6.5) can cause deficiencies in iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn) and phosphorus (P), while a pH of 5.0–5.5 can cause molybdenum deficiency (especially in poinsettia). Adding ammonium nitrate (34-0-0) at 400 g/m^3 may reduce the pH by approximately 0.5.

Ready-made mixes

Most commercially prepared mixes have been tested and will perform well when managed properly. When comparing prices between commercial mixes and custom mixing (your own), consider the costs of materials, mixing, equipment, storage space and labour. Smaller operations often use ready-made mixes. Some manufacturers will blend and deliver mixes to growers' specifications. The ready-made mixes usually follow the above outline of ingredients, although the third major ingredient (Turface® or sand) is usually omitted. Most ready-made mixes have a pH of 5.5–6.0 and an EC of 1.2–1.8 mS/cm using the SME method, while the water-holding capacity is approximately 70% on a volume basis after a 15-cm pot is totally saturated and allowed to drain.

Composts

Some growers may choose to use composted material as part of their soilless mix. Composts may contain antagonistic fungi and bacteria (to suppress plant diseases) as well as other beneficial microorganisms (such as nitrifying bacteria). Composts made from assortments of organic byproducts are available in bulk from various suppliers at relatively low costs. These may be used successfully as amendments, but it is advisable to check pH and soluble salts before use.

Common problems with soilless mixes

- Mixing the ingredients of a soilless mix for too long grinds the particles together, breaking them down and thereby destroying medium structure. A general guideline is 3–5 minutes at 12–14 rpm.

- Rewetting a soilless mix after it has dried out is difficult, but not impossible. Use several light waterings or mist applications. Alternatively, add a wetting agent to the water at approximately 1 mL/L of warm water. Normally, the wetting agent is added when mixing the ingredients. Adding granulated rockwool or vermiculite improves the rate of rewetting after severe drying out. Excessive levels of wetting agent incorporated into the medium (e.g. 2–3 times the recommended rate) can result in the development of only a few long stringy roots or a failure of the roots to penetrate the medium. This may cause overall stunting of sensitive species, including impatiens, begonia and cucumber.

- Algal growth on the surface may restrict seedling emergence, reduce water penetration and/or serve as a food source for fungus gnats. Some fungicides may reduce algal growth. As the plants grow, reduced light levels on the surface will also restrict development of algae. Agribrom added to the irrigation water at 5–10 ppm of residual bromine will help to control and/or prevent algal growth. Algae-free irrigation water also reduces this problem.

- Optimal nutrient levels are usually higher than in soil mixes, therefore keep the crop well fertilized.

Soluble salts readings can safely be about twice as high as those in a soil mix.

- Symptoms of magnesium deficiency show up quickly on crops such as tomato and chrysanthemum. This is because most conventional water-soluble "complete" fertilizers do not contain magnesium. Preplant incorporation or separate feedings of Epsom salts (magnesium sulphate) or magnesium nitrate will help prevent this situation.

The Role of Nutrients in Plant Growth

Plant nutrients can be divided (depending on the quantity of each required by the plant) into macro- and micronutrients (see Table 3-7. *Macro- and Micronutrients in Plants*, on this page), which also indicates the form in which the element is taken up by the plant and its mobility within the plant.

Table 3–7. Macro- and Micronutrients in Plants

Elements	Form	Mobility
Macronutrients		
Carbon (C)	Carbon dioxide (CO_2)	M
Hydrogen (H)	Water (H_2O)	M
Oxygen (O)	CO_2, H_2O	M
Nitrogen (N)	Ammonium (NH_4^+), Nitrate (NO_3^-)	M
Phosphorus (P)	Dihydrogen phosphate ($H_2PO_4^-$)	M
Potassium (K)	Potassium (K^+)	M
Calcium (Ca)	Calcium (Ca^{2+})	I
Magnesium (Mg)	Magnesium (Mg^{2+})	M
Sulphur (S)	Sulphate (SO_4^{2-}), Sulphur dioxide (SO_2)	M
Sodium (Na)	Sodium (Na^+)	N/A
Silicon (Si)	H_4SiO_4	N/A
Micronutrients		
Iron (Fe)	Ferrous (Fe^{2+}), Ferric (Fe^{3+})	I
Manganese (Mn)	Manganese (Mn^{2+})	I
Copper (Cu)	Copper (Cu^{2+})	I
Zinc (Zn)	Zinc (Zn^{2+})	I
Molybdenum (Mo)	Molybdate (MoO_4^{2-})	M
Boron (B)	Boric acid (H_3BO_3)	I
Chlorine (Cl)	Chloride (Cl^-)	M
Aluminum (Al)	Aluminum (Al^{3+})	M

M = mobile, I = immobile, N/A = not available

There are two main factors affecting the mineral content of a plant. The first is genetically determined and accounts for the fact that nitrogen and potassium content of many plants (46%) is about 10 times higher than that of phosphorus and magnesium, which are in turn 100–1,000 times higher than most micronutrients.

The second is the availability of nutrients in the growing medium and the ability of the plant to absorb them. In practice, this is the only factor growers can influence. Up to a certain level, the nutrient content of a given plant increases with a higher content of nutrients in the growing medium. Beyond this optimum level, no benefit can be expected from further increase in availability.

Uptake and Translocation of Nutrients

Macronutrients

In general, all macronutrients except calcium are mobile within the plant. Mobile nutrients can move in both the xylem and phloem and will be translocated to where they are most needed, usually developing shoots, flowers or bracts.

- **Carbon** – is taken up primarily in the form of CO_2 through the stomata in the leaves. It is then transformed into organic material through the process of photosynthesis. To a lesser extent it may also be taken up in the bicarbonate form (HCO_3^-) from the nutrient solution.

- **Hydrogen** – water is the major supplier of H^+ through absorption by the root hairs.

- **Oxygen** – is taken up as CO_2 during daylight, and as oxygen dissolved in water through the roots.

- **Nitrogen** – both ammonium (NH_4^+) and nitrate (NO_3^-) forms can be absorbed by the roots and metabolized by the plants. The rate of NO_3^- uptake is usually greater than that of NH_4^+. However, this depends strongly on pH. NH_4^+ uptake occurs best in a neutral medium and decreases with a lower pH. The reverse is true for NO_3^-. High carbohydrate levels in the plant (e.g. during summer) favour uptake of NH_4^+. Within the xylem, nitrogen is transported as nitrate and amino acids.

- **Phosphorus** – the majority of P is actively taken up (from very low concentrations in the soil to higher levels in the xylem) as $H_2PO_4^-$.
- **Potassium** – is taken up as K^+, often actively, and is mobile within the plant.
- **Calcium** – is absorbed passively (from higher concentrations in the soil to lower concentrations in the plant) as Ca^{2+}. Calcium in the xylem sap is translocated in an upward direction within the transpiration stream, and thus depends on transpiration rate and humidity (or vapour pressure deficit). Uptake is also favoured by NO_3^-. Within the plant, calcium is not mobile.
- **Magnesium** – the competitive effects of other cations (e.g. potassium and ammonium) are important in determining rate of magnesium uptake. It is taken up passively by the transpiration stream and is mobile in the xylem.
- **Sulphur** – plants absorb sulphur mainly in the form of sulphate (SO_4^{2-}), which may be taken up actively.

Micronutrients

All micronutrients are essentially immobile. They can be absorbed by the roots, moved through the plant in the transpiration stream and distributed to various plant parts. However, they cannot be moved out of the various plant tissues and redistributed to other plant parts if needed.

- **Iron** – uptake is influenced by rate of plant metabolism, as well as by the presence of other cations such as manganese (Mn^{2+}) and copper (Cu^{2+}). Iron uptake is depressed by high pH, root damage, and high levels of phosphate, manganese, boron and calcium; it is enhanced by high ammonium (NH_4^+). Iron (Fe^{3+}) is not mobile between plant parts.
- **Manganese** – uptake is influenced by plant metabolism (similar to iron). Low soil temperature causes low metabolic activity and therefore reduces uptake (e.g. roses in soil beds in winter). Manganese is relatively immobile in the plant. Young plant tissue is usually rich in Mn^{2+}. Manganese availability is enhanced by low pH.
- **Copper** – similar to iron and manganese. Copper (Cu^{2+}) is not very mobile within the plant but can be translocated from older to younger leaves. There are generally very low levels in the plant compared to other micronutrients.
- **Zinc** – there is some disagreement as to whether zinc (Zn^{2+}) uptake is passive or active, although most researchers consider it active. It has a strong interaction with copper. Zinc is not very mobile within plants.
- **Molybdenum** – there is not a great deal known about molybdenum (MoO_4^{2-}), except that poinsettia is one of a few plant species known to be sensitive to low levels. Molybdenum is important in the function of a major enzyme in plant metabolism.
- **Boron** – is likely taken up as undisassociated boric acid (H_3BO_3) and follows water flow through the roots. It is immobile within the plant and is concentrated more in older rather than younger leaves. Deficiency is found in the plant tip and toxicity in the older leaves.

Nutrient Analysis

Testing of water, growing media and tissue for nutrient analysis can be done through laboratories in Ontario (see Appendix C. *Greenhouse Media, Nutrient Solutions and Tissue Testing Laboratories in Ontario,* on page 130).

Water

The raw water used for irrigation purposes should contain all the major elements needed for plant nutrition; however, the quantities must be adjusted based on a nutrient analysis. Water analysis will also indicate whether the water source is contaminated (not by microbial contamination) or whether the concentration of specific ions such as fluoride (F^-) or boron (B) may be too high. In addition, the bicarbonate level has to be known (not necessarily the pH) so the required amount of acid can be calculated to obtain a given pH. Table 3-8. *Maximum Desirable Concentrations of Specific Ions in Raw Water Used for Irrigation Purposes in a Greenhouse Using Soilless Substrates (Rockwool, Oasis, Peat or Coir),* on page 31, lists the most common elements involved in plant nutrition and desirable levels in raw water to be used for irrigation.

Table 3–8. Maximum Desirable Concentrations of Specific Ions in Raw Water Used for Irrigation Purposes in a Greenhouse Using Soilless Substrates (Rockwool, Oasis, Peat or Coir)

Element	Maximum Desirable (ppm)
Nitrogen (NO_3^-)	5
Phosphorus ($H_2PO_4^-$)	5
Potassium (K^+)	5
Calcium (Ca^{2+})	120
Magnesium (Mg^{2+})	25
Chloride (Cl^-)	100
Sulphate (SO_4^{2-})	200
Bicarbonate (HCO_3^-)	30–60
Sodium (Na^+)	60
Iron (Fe^{3+} or Fe^{2+})	5
Boron (B)	0.5
Zinc (Zn^{2+})	0.5
Manganese (Mn^{2+})	1.0
Copper (Cu^{2+})	0.2
Aluminum (Al^{3+})	5
Molybdenum (Mo)	0.02
Fluoride (F^-)	1
pH (H^+)	5.0–7.0

Source: The information in this table is historical data developed and adapted over time by Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and University of Guelph greenhouse specialists.

Comments regarding the various elements:

- **N, P, K** – Although used for fertilization purposes, the presence of high levels of these elements (nitrogen, phosphorus and potassium) in the raw water indicates contamination.

- **Ca^{2+} and Mg^{2+}** – The maximum desirable levels described above provide adequate levels of nutrition for most crops. Higher values do not necessarily mean toxicity, but can contribute to the hardness of the water.

- **HCO_3^-** – Most water sources in southern Ontario contain bicarbonates (HCO_3^-) in excess of the given range. Bicarbonates are not very toxic, but levels of 250 ppm or higher may create problems for plant growth. High levels provide a high alkalinity (pH), which over time may increase pH levels in the growing medium. The precipitation of calcium and/or magnesium carbonates causing leaf residues and the plugging of emitters is another disadvantage of high carbonate levels. Neutralize high bicarbonate levels by using nitric, phosphoric or sulphuric acid (see *Adjusting the pH*, on page 23).

- **Fe^{3+}** – In its oxidized form, iron has a low solubility and can therefore easily precipitate as amorphous iron hydroxide, which plugs emitters. For drip-irrigation systems, levels higher than 0.25 ppm are undesirable.

- **B** – Boron can be quite toxic to plants and should be carefully controlled in substrate culture (less than 0.5 ppm) or for a recirculating system (less than 0.25 ppm).

- **Zn^{2+}** – Zinc can be found in water sources that have been in contact with galvanized metal (e.g. the rainwater from a greenhouse roof using galvanized gutters). Again, the ions may accumulate in recirculating systems.

- **Mn^{2+}** – Although manganese is not often a problem except under specific circumstances (e.g. steam pasteurization), it is believed to be toxic at high levels.

- **Cu^{2+}** – Copper levels may be higher than 0.2 ppm if organic media are used.

- **Al^{3+}, Mo, F^-** – Aluminum, molybdenum and fluoride are not commonly found at high concentrations in the water source. However, fluoride can cause serious damages to monocotyledons (lily, dracaena, spider plant). Cleaning compounds for greenhouse roofs (to remove white wash), which often contain fluoride, should not be allowed to drain into a cistern or pond.

- **pH** – Although hydrogen ions are not considered a nutrient element it is important to include this factor, as the availability of most nutrients is pH-dependent. For instance, most positively charged ions such as iron (Fe), manganese (Mn) and calcium (Ca), as well as phosphates, are more soluble (and therefore more available to the plant) at a low pH, while molybdenum is more available at a higher pH. Most water sources in Ontario have a pH of approximately 7.5, due to high levels of bicarbonates. Acidification may be required (see *Adjusting the pH*, on page 23). A pH lower than 5.0 is detrimental to the structure of rockwool slabs.

See Appendix C. *Greenhouse Media, Nutrient Solutions and Tissue Testing Laboratories in Ontario,* on page 130, for laboratories in Ontario that are able to analyze water, nutrient solutions and media.

Soilless media

Media testing for nutrient analysis used to be carried out by mixing water with the soil at a ratio of 1:2 (air-dried soil:water), a technique called the Spurway test. Now the Saturated Media Extraction (SME) method using distilled water is the most widely used in North America; it measures the nutrients directly in the extract. This procedure provides an estimate of what is readily available to the plant in the root zone.

Sampling the growing medium

- **Soil** – Using a soil probe, take approximately 20 samples of the area (ground beds) at a depth between 10–25 cm and bulk the samples. Mix the bulked sample well, take a representative sample (approximately 600 g), put in a plastic bag and send for SME analysis (see *How to measure EC of the growing medium,* on page 20, and Appendix C. *Greenhouse Media, Nutrient Solutions and Tissue Testing Laboratories in Ontario,* on page 130). Analysis is conducted on a fee-for-service basis. For seasonal crops, have the soil tested well before the crop is planted. Allow enough time between sending the samples and planting the crop to make nutrient or pH adjustments.

- **Potting media** – Sample only the bottom two-thirds of the potting substrate; do not include the top layer, particularly when the crop is being sub-irrigated. Bulk together 20 samples and from that take a representative sample of approximately 600 g, place in a plastic bag and send to the laboratory. Growers should conduct their own EC and pH tests (between regular sampling for laboratory analysis) by drenching a number of pots with distilled water and measuring the leachate. These results compare fairly closely to the SME used by a laboratory (see *Interpretation of EC data,* on page 20) and give an accurate indication of the total nutrient status, but not that of the individual elements. To accurately track nutrient levels in the media, collect bi-weekly samples.

For interpretation of results and adjustments to the growing medium, consult a greenhouse floriculture specialist.

Foliar

In floriculture, leaf tissue analysis is primarily used as a diagnostic tool to verify deficiency or toxicity symptoms, but can also be used to monitor nutrient levels during the cropping period. Different plant parts contain different levels of nutrients, but analysis of leaf tissue is most commonly used for diagnosing nutrient availability (uptake) in the soil. The mineral content of plants is usually expressed as a percentage on a dry weight basis for the macro-elements (nitrogen, phosphorus, potassium, etc.). For micro-elements (iron, manganese, copper, zinc, boron, molybdenum), mineral content may be expressed as milligram per gram (mg/g) or parts per million (ppm) of plant dry matter. The age of the plant parts is important as well. Young plant tissue tends to have higher contents of nitrogen, phosphorus and potassium compared to older tissue, which generally has higher levels of calcium, manganese, iron and boron. Therefore, harvest the most recently matured leaves of a plant for tissue analysis, if testing regularly to monitor the nutrient status.

Foliar analysis is often a more accurate method of assessing the micronutrient status of the crop or fertility program, rather than analyzing the media micronutrient levels. Sample the most recently matured leaves from several plants unless otherwise indicated (usually 30–50 leaves are sufficient). Avoid leaves with disorders unless they are to be diagnosed, in which case treat them as a separate sample. Ensure that samples are not contaminated with pesticides or foliar applications of fertilizer. If in doubt, rinse the leaves in distilled water and let them dry before packaging and sending them to the laboratory. Laboratories generally prefer paper bags over plastic so that the leaves do not rot in transport.

Table 3-9. *Tissue Analysis Guidelines,* on page 33, provides an overview of the desirable ranges of nutrients. Factors that can affect nutrient content include plant age, position on plant (upper versus lower leaves), cultivar, season, fertilizer regime, number of days after fertilization, media pH, growth regulator application, presence of disease and temperature. These values are a guide only to the appropriate nutritional status for these plants.

Table 3-9. Tissue Analysis Guidelines

Nutrient	African violet	Alstroemeria	Azalea	Rieger begonia	Wax begonia	Zygocactus (Schlumbergera)	Caladium
Nitrogen (%)	2.2–2.7	3.8–7.6	2.2–2.8	3.4–4.6	4.4–5.2	2.7–3.7	3.6–4.9
Phosphorous (%)	0.2–0.9	0.3–0.7	0.2–0.5	0.4–0.8	0.3–0.4	0.5–0.9	0.4–0.7
Potassium (%)	1.5–6.0	3.7–4.8	0.7–1.6	2.0–3.5	3.4–4.2	6.2–7.1	2.3–4.1
Calcium (%)	0.6–1.7	0.6–1.4	0.2–1.6	0.7–2.4	1.3–2.1	0.7–0.9	1.1–1.6
Magnesium (%)	0.7–1.1	0.2–0.4	0.1–0.6	0.3–0.8	0.6–1.0	1.6–2.2	0.1–0.3
Iron (ppm)	70–320	175–275	50–150	80–390	100–260	105–110	65–90
Manganese (ppm)	35–490	60–90	30–300	35–190	90–355	35–130	110–135
Zinc (ppm)	20–80	35–70	5–60	20–30	50–65	50–65	125–135
Copper (ppm)	5–30	5–15	5–15	5–10	10–15	10–15	5–10
Boron (ppm)	30–200	10–50	15–100	35–130	30–40	65–70	95–145

Nutrient	Calla	Carnation	Chrysanthemum	Cyclamen	Dieffenbachia[1]	Easter lily	Exacum
Nitrogen (%)	2.9–3.0	3.0–5.0	4.0–6.0	2.9–5.0	3.0–4.0	2.4–4.0	3.8–5.3
Phosphorous (%)	0.3–0.4	0.1–0.5	0.2–1.2	0.4–1.0	0.7–1.0	0.1–0.7	0.3–0.7
Potassium (%)	3.9–4.4	2.0–6.0	1.0–10.0	1.2–4.5	6.4–8.2	2.0–5.0	2.3–3.4
Calcium (%)	0.9–1.1	0.6–2.0	0.5–4.6	0.3–1.3	1.9–2.4	0.2–4.0	0.5–0.8
Magnesium (%)	0.3–0.4	0.2–0.6	0.1–1.5	0.4–1.3	0.4–0.8	0.3–2.0	0.4–0.7
Iron (ppm)	95–130	30–150	20–750	150–550	50–300	100–250	55–155
Manganese (ppm)	635–690	30–445	25–375	100–500	50–300	50–250	70–165
Zinc (ppm)	30–45	15–75	5–35	30–100	40–200	30–70	25–85
Copper (ppm)	5–10	5–30	5–50	5–20	3.5–30	5–25	5–75
Boron (ppm)	30–40	20–400	20–200	70–350	10–30	20–50	25–60

Nutrient	Ficus benjamina[1]	Freesia	Fuchsia	Ivy geranium	Regal geranium	Seed geranium	Zonal geranium
Nitrogen (%)	2.0–2.5	2.7–5.6	2.8–4.6	3.4–4.4	3.0–3.2	3.7–4.8	3.8–4.4
Phosphorous (%)	0.2–0.4	0.4–1.2	0.4–0.6	0.4–0.7	0.3–0.6	0.3–0.6	0.3–0.5
Potassium (%)	2.1–2.5	3.1–5.9	2.2–2.5	2.8–4.7	1.1–3.1	3.3–3.9	2.6–3.5
Calcium (%)	1.7–2.5	0.4–1.0	1.6–2.4	0.9–1.4	1.2–2.6	1.2–2.1	1.4–2.0
Magnesium (%)	0.3–0.4	0.3–1.8	0.4–0.7	0.2–0.6	0.3–0.9	0.2–0.4	0.2–0.4
Iron (ppm)	50–200	80–115	95–335	115–270	120–225	120–340	110–580
Manganese (ppm)	25–100	30–540	75–220	40–175	115–475	110–285	270–325
Zinc (ppm)	20–75	40–110	30–45	10–45	35–50	35–60	50–55
Copper (ppm)	5–10	5–130	5–10	5–15	5–10	5–15	5–15
Boron (ppm)	20–40	30–100	25–35	30–280	15–45	35–60	40–50

TABLE 3–9. Tissue Analysis Guidelines (con't)

Nutrient	Gerbera	Gloxinia	Hibiscus	Hydrangea	Common impatiens	Nephrolepis[1]	New Guinea impatiens
Nitrogen (%)	3.3–4.1	3.3–3.8	3.5–4.5	2.0–3.8	4.3–5.3	1.7–2.5	3.3–4.9
Phosphorous (%)	0.3–0.7	0.3–0.5	0.2–0.6	0.3–2.5	0.6–0.8	0.3–0.6	0.3–0.8
Potassium (%)	3.1–3.9	4.5–5.0	2.0–2.9	2.5–6.3	1.8–2.8	2.5–3.9	1.9–2.7
Calcium (%)	0.9–4.2	1.5–2.2	1.9–2.3	0.8–1.5	2.9–3.3	0.9–1.3	1.9–2.7
Magnesium (%)	0.3–2.8	0.4–0.5	0.5–0.7	0.2–0.4	0.6–0.8	0.6–0.7	0.3–0.8
Iron (ppm)	80–130	70–150	60–75	85–115	405–685	30–300	160–890
Manganese (ppm)	65–260	95–170	135–180	100–345	205–490	49–181	140–245
Zinc (ppm)	30–80	20–35	35–50	50–105	65–70	52–149	40–85
Copper (ppm)	5–10	5–20	5–10	5–10	10–15	10–15	5–10
Boron (ppm)	25–50	30–35	20–25	35–50	45–95	20–40	50–60

Nutrient	Kalanchoe	Petunia	Poinsettia	Primula	Rose	Snapdragon	Streptocarpus[1]	Vinca
Nitrogen (%)	2.5–5.0	2.8–5.8	4.0–6.0	2.5–3.3	3.0–5.0	4.0–5.3	2.0–3.5	4.9–5.4
Phosphorous (%)	0.2–0.5	0.5–1.2	0.2–1.0	0.4–0.8	0.2–0.3	0.2–0.6	0.1–0.7	0.4–0.6
Potassium (%)	2.0–4.8	3.5–5.5	1.5–5.0	2.1–4.2	1.8–3.0	2.2–4.1	4.8–5.5	2.9–3.6
Calcium (%)	1.1–4.5	0.6–4.8	0.4–2.0	0.6–1.0	1.0–1.9	0.5–1.4	1.2–1.9	1.4–1.6
Magnesium (%)	0.4–1.0	0.3–1.4	0.2–1.0	0.2–0.4	0.2–0.4	0.5–1.0	0.3–0.5	0.4–0.5
Iron (ppm)	75–200	40–700	100–300	75–155	50–150	70–135	90–260	95–150
Manganese (ppm)	60–250	90–185	45–300	50–80	30–900	60–185	130–300	165–300
Zinc (ppm)	25–80	30–90	25–150	40–45	15–50	30–55	85–130	40–45
Copper (ppm)	5–20	5–45	5–15	5–10	5–25	5–15	15–20	5–10
Boron (ppm)	30–60	20–50	20–200	30–35	20–60	15–40	55–65	25–40

[1] Numbers from *Guide Values for Nutrient Element Contents of Vegetables and Flowers under Glass*, Glasshouse Crops Research Stations, Aalsmeer and Naaldwijk, 1987. (Assembled and updated by R.E. Widmer, University of Minnesota, June 1985. Expanded and updated by J.M. Dole and H.F. Wilkins, University of Minnesota, October 1988, Department of Horticultural Science and Landscape Architecture).

Recommended portion of plant to sample:

- chrysanthemum – uppermost leaves from mature flowering shoots
- exacum – shoot tips with one pair of mature leaves and all immature leaves
- rose – uppermost five-leaflet leaf on flowering stems
- other crops – the most recently mature leaf

Symptoms of Nutrient Deficiency

(Source: *Diagnosing Nutrient Disorders in Greenhouse Crops*, C. Rosen and J. Erwin, University of Minnesota).

Nutritional interactions

Nutritional problems in greenhouse crops can be common because of the high rate of growth, the different specific requirements of each crop, the limited rooting volume of the container and the limited nutrient reserve of the medium in which the crop is grown. Both the amount of nutrients being supplied and their balance play important roles in producing high-quality crops. Changing the level of one nutrient in a solution can affect the uptake or transport through the plant of another. Although interactions between nutrients can be either positive or negative, it is usually the negative interactions that are most well documented.

Nutrient interactions become a factor in two situations:

- when the levels of two elements are near the deficiency range

- when one element is supplied in excessive amounts while another is at levels that are marginally sufficient

The precise nature of the interaction depends on the nutrients involved and the plant species. It may be the result of precipitation reactions occurring in the soil solution, or the result of competition during ion uptake, translocation or metabolic function (see Table 3-10. *Some Common Interactions Between Nutrients*, on this page). In many cases, the mechanism for the interaction may not be completely understood. These antagonistic effects become important when nutrient levels are low.

Table 3-10. Some Common Interactions Between Nutrients

If excessive in media or tissue:	May cause deficiency of:
Ammonium	Calcium
Nitrate	Potassium
Phosphorus	Iron, zinc, copper
Potassium	Magnesium, calcium
Calcium	Magnesium, boron
Magnesium	Potassium, calcium
Manganese	Iron
Iron	Manganese
Zinc	Manganese, iron
Copper	Manganese, iron, zinc

Consider nutrient interactions and proper balance in relation to proper supply. Nutrient supply is important because optimal nutrient ratios in the solution or the plant tissue can be achieved even when both elements are in the deficient or toxic range.

Diagnosing Nutrient Disorders

With nutrient disorders, remember that once visual symptoms are present, marketability of the plants may have already been reduced. Follow rigorous soil-testing programs to detect potential problems before they result in crop losses.

In most cases, symptoms of nutritional disorders occur in defined patterns and are specific for each nutrient. Elements that are mobile within the plant generally induce deficiencies on the older (lower) leaves first, while immobile elements induce deficiencies on the younger (upper) leaves. In some cases, pesticide toxicity or disease symptoms may resemble nutrient deficiencies or toxicities.

In addition, symptoms of nutritional disorders are often species or cultivar dependent. Use soil and tissue analysis to help confirm whether the symptoms are nutritional.

The following symptoms of nutrient deficiency and/or toxicity (for nitrogen, phosphorus, potassium, magnesium and sulphur) generally affect lower leaves first and may progress to younger leaves as the problem becomes more severe.

Nitrogen

Deficiency

- Leaves turn pale green to yellow.
- Oldest leaves are affected first, but in severe cases, the whole plant may be yellow. Growth is usually stunted. Symptoms are very similar to sulphur deficiency.

Excess ammonium

- Plant growth is restricted.
- Leaves are yellow.
- Marginal necrosis occurs.
- The growing point dies.
- High ammonium (generally during the winter months) will interfere with uptake and/or translocation of potassium, magnesium and calcium, thereby inducing calcium deficiency and reduced potassium and magnesium content of plant tissue.

Excess nitrate

- Most plants tolerate high nitrate levels without any symptoms.
- Nitrate enhances phosphorus and potassium uptake.
- Excessive nitrate will stimulate vegetative growth and may delay flowering.

Phosphorus

Deficiency

- Leaves appear reddish-purple; lower leaves are yellowish.
- Oldest leaves are affected first; necrosis and leaf drop if severe.
- Plant growth is stunted.
- Phosphorus deficiency may be induced under high pH (>7.4) or low pH (<5.0) conditions in soilless media.

Excess

- May induce micronutrient deficiency symptoms by inhibiting iron, zinc and copper uptake and/or translocation, possibly due to precipitation of phosphates.

Potassium

Deficiency

- Leaves develop grey or tan areas near the margins.
- Oldest leaves are affected first with characteristic scorching of the leaf tips and around the margins.
- In some plants, spotting or chlorosis between the veins may occur.
- Growth may be bushy.

Excess

- May cause salt burn at very high rates.
- If magnesium levels are marginal, will induce magnesium deficiency.

Magnesium

Deficiency

- Older leaves turn yellow between the veins (interveinal chlorosis).
- In severe cases, younger leaves may be affected and older leaves may develop necrotic spots and then drop off.
- Deficiency can be induced by high potassium levels.

Excess

- Plants can tolerate high levels of magnesium without adverse effects.
- High levels of magnesium can cause deficiencies of potassium and calcium in plant tissue.

Sulphur

Deficiency

- There is a general yellowing of the plant; leaf veins are often yellow.
- Symptoms are similar to nitrogen deficiency.

Excess

- Plants can tolerate high levels of sulphur; however, uptake of molybdenum will be reduced.

The following symptoms of nutrient deficiency and/or toxicity (for calcium, boron, copper, iron, manganese, molybdenum and zinc) generally affect younger or upper leaves first.

Calcium

Deficiency

- Growing points of plants may die.
- Youngest leaves are affected first.
- Root tips die; root growth is slow.
- In some plants, leaf edges or tips are yellow or scorched (often termed leaf-edge or leaf-tip burn).
- Deficiency can be induced by high levels of ammonium and excessively wet or dry conditions.

Excess

- Plants can tolerate high levels of calcium without adverse effects.
- High levels of calcium can cause lower levels of potassium and magnesium in plant tissue.

Boron

Deficiency

- Usually occurs on younger plant tissue.
- Young leaves are often dark green, thick and brittle.
- Growing points die, and leaves appear small and distorted, with multiple shoot development. "Witch's broom" on rose is common.

Excess

- Can be highly toxic to some plants.
- Toxicity usually occurs on the oldest leaves as a scorching of the margins.

Copper

Deficiency

- Yellowing or dieback of youngest leaves occurs.
- Yellowing between the veins may appear.
- There is a distortion of the leaves with stunted, strap-like growth.
- High levels of phosphorus may induce copper deficiency.

Excess

- May induce iron deficiency and cause stunted root systems.

Iron

Deficiency

- There may be yellowing between the veins on the youngest leaves, although veins remain green (interveinal chlorosis). They also may turn totally yellow to white with necrosis.
- High levels of phosphorus may induce iron deficiency.
- Oxygen deprivation due to over-watering will trigger iron chlorosis.
- High pH conditions as well as low soil temperatures will cause iron deficiency. When high pH is the cause, it is recommended that iron chelate in the EDDHA (strongest over the widest pH) be used to correct iron related symptoms.

Excess

- Most plants can tolerate high levels of iron without adverse effects.
- Chlorotic spots eventually become reddish-brown with eventual collapse of affected tissue.
- High levels may induce magnesium deficiency in some plants.

Manganese

Deficiency

- Manganese deficiency appears similar to iron deficiency.
- Yellowing between the veins of the youngest leaves occurs; usually leaves do not turn white and necrotic.
- Usually only the main veins remain green, causing a fishbone-like appearance.
- Occurs under high pH conditions and/or low soil temperatures.

Excess

- Reddish-brown to black spots appear on lower leaves between veins; the leaves are yellow.
- Occurs under low-pH conditions.

Molybdenum

Deficiency

- Young leaves appear pale, distorted and narrow with a whiptail appearance.
- Young mature leaves may show interveinal chlorosis and in-rolling of leaf margins; ultimately yellowing tissue becomes necrotic.
- In some plants, leaf margins may be scorched.
- Occurs most frequently under low-pH conditions.
- Phosphorus and magnesium will enhance uptake, while high sulphur will decrease uptake.

Excess

- Plants can tolerate high levels of molybdenum without adverse effects.

Zinc

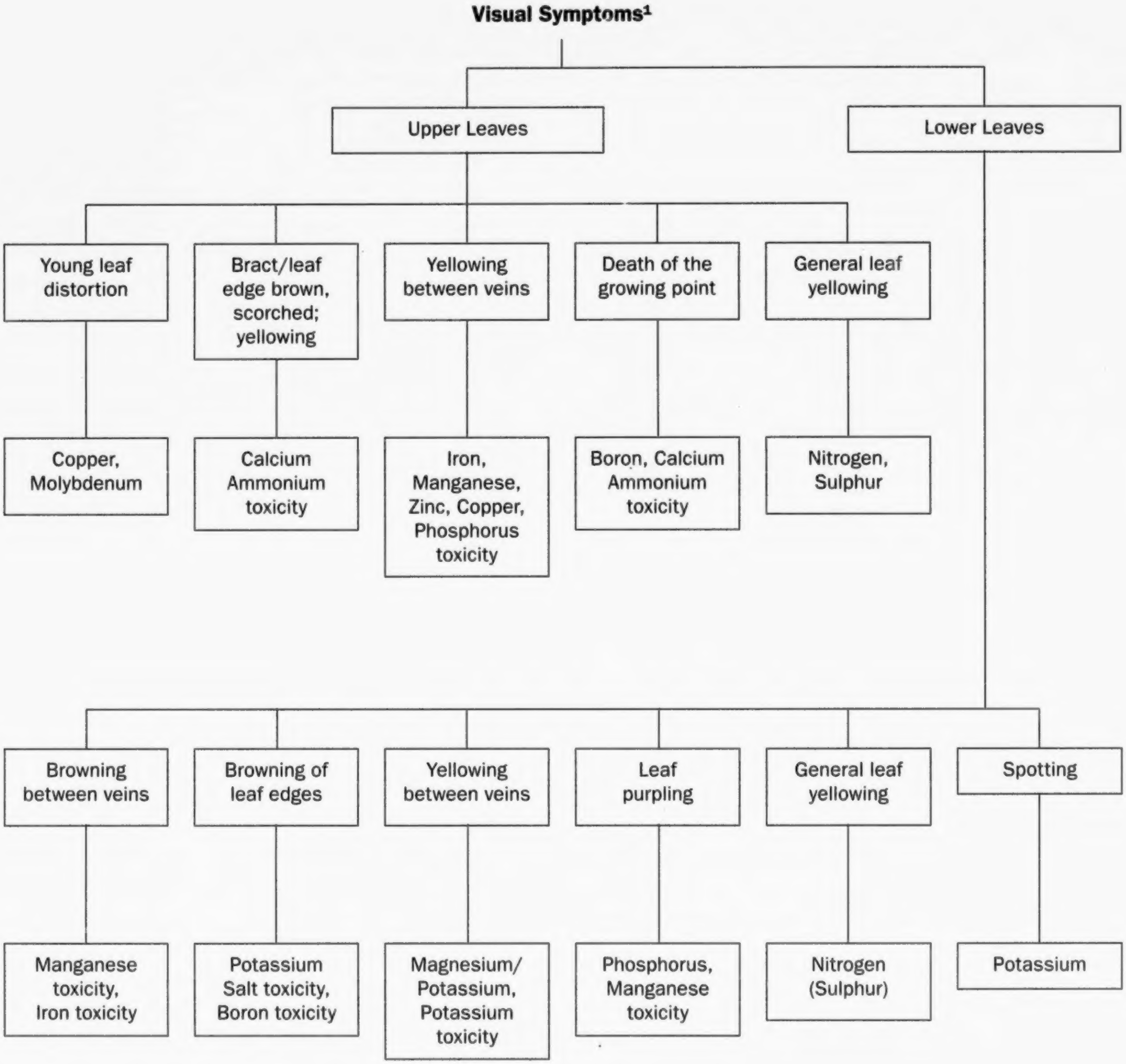
Deficiency

- Younger leaves are affected first and may show signs of yellowing between the veins.
- Other symptoms may include short internodes and rosetting of leaves.
- High levels of phosphorous may induce zinc deficiency.
- Occurs under high-pH conditions.

Excess

- May depress uptake of phosphorus and iron in some plants.
- Occurs under low-pH conditions.
- Results in reduced root growth and leaf expansion.

Figure 3–1. Key to Determining Nutrient Disorders in Greenhouse Crops


Visual Symptoms[1]
Upper Leaves
Lower Leaves
Young leaf distortion
Bract/leaf edge brown, scorched; yellowing
Yellowing between veins
Death of the growing point
General leaf yellowing
Copper, Molybdenum
Calcium Ammonium toxicity
Iron, Manganese, Zinc, Copper, Phosphorus toxicity
Boron, Calcium Ammonium toxicity
Nitrogen, Sulphur
Browning between veins
Browning of leaf edges
Yellowing between veins
Leaf purpling
General leaf yellowing
Spotting
Manganese toxicity, Iron toxicity
Potassium Salt toxicity, Boron toxicity
Magnesium/ Potassium, Potassium toxicity
Phosphorus, Manganese toxicity
Nitrogen (Sulphur)
Potassium

[1] Symptoms refer to deficiency unless otherwise stated.

4. Integrated Insect and Mite Management

This chapter discusses the tools of integrated pest management (IPM) for insect and mite pests. IPM is a pest control philosophy that uses all available control strategies to maintain pest populations of insects, mites or disease organisms below an economic injury level. The routine spraying of pesticides for insurance purposes is no longer likely to achieve effective control. In recent years, this practice has led to a number of problems, including:

- pest resistance (which is discussed further under the section *Chemical Control* later in this chapter)
- environmental concerns over pollution and groundwater contamination that make it important to reduce use and misapplication of pesticides and to focus on pesticides with a more environmentally friendly profile
- personal health and safety concerns relating to potential exposure of applicators and workers to pesticides, as well as pesticide residues in greenhouses. Refer to Chapter 1, *Using Pesticides in Ontario,* on page 1 and Chapter 2, *Safe Use of Pesticides,* on page 7 for more information on working safely with pesticides

IPM concepts do not advocate a continuous pesticide spray program to eradicate pests, but rather promote the integration of cultural, physical, biological and chemical control strategies. A well structured and routine pest monitoring program controls the decision-making process in IPM. The concepts of IPM are also further discussed in the context of disease management. See Chapter 7, *Integrated Disease Management,* on page 69.

Monitoring

Careful monitoring provides reliable information to guide an integrated pest management program. The most common greenhouse-monitoring technique is the use of yellow sticky traps (cards or tape) to collect many species of flying insects. These are especially effective for whitefly, thrips, leaf miner, fungus gnats, shoreflies and winged aphids. Note that blue sticky traps have proven to be especially attractive to western flower thrips. However, if a variety of pests is present, yellow traps are a better choice.

When using sticky cards, provide sufficient numbers to adequately monitor the entire greenhouse. Use one card every 100–200 m^2 and change the traps regularly. In spring and summer, this usually means changing the cards every week when recording the pest numbers. In winter, when pest numbers are lower, it may be possible to change sticky cards less frequently, however pest numbers should still be recorded weekly.

Another important, and often overlooked, monitoring technique is a routine and structured crop inspection program. It is essential for monitoring the presence of plant diseases, mites, wingless aphids or the immature stages of whitefly and leaf miner. Adopt a regular sampling pattern that provides good coverage of the whole greenhouse, including entry points and areas of concern. Concentrate on known susceptible crops or areas within the greenhouse that are known hot spots. Again, keep weekly records.

To monitor for disease, inspect foliage weekly and roots (or, for vegetable crops, the bases of the plants) every two weeks. Check electrical conductivity (EC) and pH biweekly for each crop grown. Detecting diseases and non-flying pests (such as aphids or mites) early makes control easier and may mean containing a problem with only a spot spray or other localized action.

To be successful, monitor on a regular basis. Record information so growers can make use of it in the future. Include:

- date
- pests identified
- location in the greenhouse
- number of insects trapped
- stage of development (e.g. adults, pupae)
- diseases present or suspected
- crop species and cultivar
- control action (pesticide used, rate, area treated, time taken, etc.)
- environmental conditions

Cultural Controls

Sanitation

Sanitation is the first step in any pest control program. If a source of infection or infestation persists due to poor hygiene, pest control programs will be expensive and frustrating. Practise proper sanitation in the greenhouse and adjoining structures (boiler rooms, etc.), in the immediate vicinity of the greenhouse and during every stage of crop production.

Proper greenhouse sanitation is a continual, year-round process. Cleanliness on its own may not control pest problems, but it is a basic component of any control program and an essential adjunct to other pest management strategies. It is important to:

- Remove dead and dying leaves and flowers. In roses, removal of all flowers (including those that will not be sold) and disposal away from the greenhouse can play a significant role in control of thrips.

- Remove crop residues and deposit them well away and downwind from the greenhouse.

- Preferably burn residues as permitted by the local municipality; alternatively, contain and dispose of them.

- Remove all weeds from inside and immediately outside the greenhouse.

- Keep walks and the surfaces of beds clean.

- Check carefully for pest infestations when bringing new plant material into the greenhouse.

- Avoid overwintering garden or house plants in the greenhouse, otherwise pests will be maintained for an early invasion of the next crop.

- Maintain good drainage to eliminate puddles and wet surfaces, as these provide ideal breeding sites for fungus gnats and shoreflies, and are a possible source of infection for waterborne diseases.

- If the greenhouse is empty between crops (which is especially likely with greenhouse vegetables, but also possible in some ornamental greenhouses), heat treatment can be an effective way to remove pest infestations. If temperatures are maintained at >40°C and humidity at <50% for 3–4 days, insect and mite pests will be effectively controlled. This is particularly suitable during the warmer months of the year when these temperatures can be achieved by simply closing the vents. Note: At higher temperatures, plastic fittings may warp.

- To prevent disease organisms from carrying over on empty structures, heating pipes, walks, benches or equipment, spray with one of these options (also see Chapter 7, *Integrated Disease Management,* on page 69):
  - A 0.5–1% final solution of sodium hypochlorite bleach. Mix 1 part common household bleach with 10 parts water to obtain a final solution of 0.5%. For a 1% solution, mix 1 part bleach to 5 parts water. Use a higher strength solution (up to 1%) in cases of serious disease outbreaks or when disinfecting wooden benches.
  - Floralife D.C.D. or Chemprocide, quaternary ammonium compounds with fungicidal and bactericidal activity.
  - Virkon, a disinfectant with fungicidal, bactericidal and virucidal activity.

Managing the greenhouse environment

Factors such as light, temperature, humidity, water and nutrients affect not only the plant, but also the pests and diseases that afflict them. The use of environmental controls to manage pests is complex because of the simultaneous effects on crop production. Look at each case carefully; every one is different. For example, humidity can play an important role in pest and disease development.

Spider mites prefer hot, dry conditions. Increasing humidity by overhead misting can help to retard the development of this pest.

During the winter months, thrips are not particularly mobile. This is probably due to low light levels (rather than to low temperatures) and it can have implications for monitoring programs. At this time of the year, yellow sticky cards may not catch thrips, even when thrips are present and actively feeding in the crop.

Air moisture affects the development of diseases such as powdery mildew and *Botrytis,* which makes these problems conducive to treatment by environmental manipulation. See Chapter 8, *Major Greenhouse Diseases,* on page 79.

Resistant cultivars

Many plant species display varietal differences in their susceptibility to insect and disease attack. Breeding of crops can provide growers with cultivars resistant to one or more insects or diseases. For example, greenhouse tomato growers seldom experience problems with *Fusarium* crown and root rot because resistant varieties have been developed. Greenhouse growers are increasingly using powdery mildew–tolerant cucumber varieties. Although ornamental plant breeders have not taken great advantage of host plant resistance, it offers potential for future advancements in pest management.

In the meantime, growers with pest problems can improve their pest management program by examining the varieties grown and how pests affect these varieties. Use susceptible varieties as indicators for pests and diseases (e.g. the colour of the flower might attract more thrips). Spot-spray the susceptible variety when pests or diseases occur to provide effective control and reduce the amount of pesticide applied; alternatively, use susceptible varieties as an intensive focus of biological control programs. Although market demands ultimately determine the varieties grown, consider whether it is possible to eliminate or reduce the amount of a susceptible variety and replace it with a more resistant one.

Soil pasteurization methods

Greenhouse media and field soils contain weed seeds, insects, bacteria and fungi that may be harmful to the plants being grown. Control of diseases caused by fungi and bacteria is discussed more thoroughly in Chapter 7, *Integrated Disease Management,* on page 69. Greenhouse media includes potting mixes and their components, unless it is guaranteed sterile or pasteurized by the manufacturer. Pasteurize soil and potting mixes to eliminate these harmful organisms. Ideally, this is accomplished without injuring beneficial soil organisms.

Steam

Steam is the most common heat source for pasteurization. There are different ways of handling steam, depending on the type of crop being grown.

When pasteurizing soil in bulk for vegetable seedlings or potted plants, some growers find it efficient to inject steam into the bottom of a wagon or similar enclosed vehicle. After cooling, move the pasteurized soil to the area in which it will be used.

Growers of cut flower or vegetable crops follow one of two techniques when steaming soil in beds:

- If ground beds are drained with agricultural tile, it is very simple to inject steam into these tiles and pasteurize the soil on the sides and above them. The top of the tile should be 40 cm below the surface and the rows on 60 cm centres.
- If tiles are not installed, cover the bed with a tarpaulin. Inject steam directly under the tarpaulin through a canvas hose or a perforated, flexible plastic field tile to ensure even distribution. Soil should be in fine tilth and free from clods and undecomposed crop remains, to allow rapid and uniform penetration of the steam.

If re-using rockwool, it is important to note that steaming time depends on the wetness of the rockwool and the steam temperature. Steaming at 90°C for 30 minutes should be adequate. Generally, the wetter the rockwool, the longer the steaming period. For this reason, the substrate should be as dry as possible before steaming. Rockwool stacked on pallets without polyethylene bags can be steam-sterilized in two hours. Rockwool wrapped in polyethylene requires five hours of steaming. Rockwool should not be stacked higher than 1.5 m. To stabilize the stacked slabs, place each row at a right angle to the previous row. In addition, leave a 2.5 cm space between individual slabs to allow for better steam penetration.

Time-temperature relationships to destroy undesirable organisms

Table 4-1. *Time-Temperature Relationships to Destroy Undesirable Organisms,* on page 42, shows the time necessary to destroy insects, weeds and various diseases at specific temperatures. It shows that most organisms of concern to growers can be eliminated under ideal conditions of 60°C for 30 minutes.

When temperatures rise above 82°C, beneficial soil organisms begin to be destroyed. If the soil is heated to a temperature that is too high for too long a time, it becomes sterile. It is then subject to a greater degree of infection, as all beneficial organisms have now been

Table 4–1. Time-Temperature Relationships to Destroy Undesirable Organisms

Weeds (most)	70°C–80°C for 15 min.
Insects and mites	60°C–71°C for 20 min.
Bacteria (most)	60°C for 10 min.
Fusarium	57°C for 30 min.
Botrytis	55°C for 15 min.
Nematodes	55°C for 30 min.
Rhizoctonia	52°C for 30 min.
Sclerotinia	50°C for 5 min.
Pythium	46°C for 40 min.

destroyed. There are many other undesirable effects of over-steaming, such as:

- excessive ammonia release
- manganese toxicity
- higher total salt levels
- destruction of organic matter

Aerated steam

Aerated steam is being used more widely than it used to be. In this system, steam mixes with air in a chamber. The mixture is used at 70°C to pasteurize soil while avoiding any of the hazards of over-steaming. Unless there are specific problems, a soil temperature of 70°C is adequate for most insect and disease problems.

Electric soil pasteurizers

Electric soil pasteurizers are useful when pasteurizing small volumes of soil and when other methods are not available. It is important to note that these can overcook the soil very easily. For the soil temperature between the finned heat sources to reach 82°C, the fins themselves must be at a higher temperature.

Chemical fumigants

Chemical fumigants such as Basamid and Vapam can be used to pasteurize soil for potting or in greenhouse beds or benches. Each of these fumigants has a specific rate and activity against soilborne insects, diseases, nematodes and weeds. Always read the manufacturer's label – some formulations may be less effective against certain types of pests. Protect crops in adjoining beds or benches from accidental exposure to escaped fumes.

Fumigants listed in Table 4-2. *Chemical Fumigants for Soil Treatments,* on this page, are effective as preplanting treatments for greenhouse soil beds, or for outdoor plantings in the case of Telone IIB and Telone C-17.

Table 4–2. Chemical Fumigants for Soil Treatments

Control of Nematodes Only	**Rate (per 100 m²)**
Telone IIB*	2.0 L
Telone C-17*	2.0 L
Control of Nematodes, Fungi, Insects and Some Bacteria	
Basamid (granular)	3.25–5 kg worked into a depth of 15–23 cm
Vapam (liquid)	10 L

* Telone IIB and Telone C-17 are registered for use on outdoor floral crops only. They will be withdrawn from the market and cannot be used after December 31, 2011.

Weed Control Methods

Control of weeds inside and outside the greenhouse is an important part of any pest management program. Weeds can provide a refuge for insect and mite pests and can act as a reservoir for diseases. A 3 m vegetation-free or carefully maintained strip of lawn around and between greenhouses will decrease the danger of invasion by insects and diseases from outside. Fescue grasses have been shown as one of the least preferred grasses of western flower thrips, which makes it useful for lawn plantings around greenhouses. For some regulated pests such as Japanese beetle, there are specific requirements for the outside perimeter of greenhouses. See Chapter 6, *Occasional Pests,* on page 61 or contact the Canadian Food Inspection Agency (see Appendix D. *Other Contacts,* on page 131).

Herbicide application, cultivation and hand weeding are the most practical methods of controlling weeds around the perimeter of greenhouses. Herbicides such as Roundup or Gramoxone can be very effective. See *Herbicides,* on page 43, for additional comments.

However, other methods may be useful to reduce the amount of labour required to keep weeds under control.

Steam

As mentioned above, steam used to pasteurize soil will kill weeds and most weed seeds if the soil temperature can be held at 70–80°C for 15 minutes. Weed seeds with hard seed coats, those along the periphery of the steam tarpaulin and those in the transition layer between soil at the appropriate temperature and cooler soil may not be killed.

Soil fumigation

Metam sodium (Vapam) and dazomet (Basamid) are useful in treating seedbeds and potting soil. Telone II can be used to treat soils used for field produced flowers. They break down in the soil to produce a gas that kills many weed seeds, nematodes and fungi that cause damping-off and other plant diseases. Do not use when plants are in other areas of the greenhouse.

Herbicides

OMAFRA Publication 75, *Guide to Weed Control,* is available from OMAFRA Resource Centres and Service Ontario Publications, and contains information on herbicides registered for use in Ontario. Treatments listed in the publication are subject to extensive field trials and observation on farms. Herbicides may be particularly useful for weed control outside, **but no herbicides are registered for use inside the greenhouse.** Inside the greenhouse, remove weeds when young to prevent seed production from occurring. For bedding plant production facilities, cover the surface of the soil with black nursery mesh to minimize weed growth.

There is potential for crop damage if any herbicide is used incorrectly. Always turn fans off to avoid drawing herbicides into the greenhouse. Do not use any phenoxy-type herbicides adjacent to the vent side of the greenhouse because of the volatility of these herbicides. Carefully follow instructions in *Guide to Weed Control* regarding chemicals, safety precautions, calibration, and care and use of sprayers. Where herbicide drift from neighbouring sources is suspected, contact an office of the Ministry of Environment (see Appendix B. *Ontario Ministry of Environment – Regional Offices Contact Information,* on page 129).

Where unwanted herbicide residues remain in the soil, applying activated charcoal can reduce the problem. The rate varies depending on the type of chemical contaminant and its concentration. A typical range is 0.5–1.5 kg/100 m^2.

Physical Control

Screening

In warmer climates where pests occur outside all year, screening has become an established part of IPM programs. While not as common in temperate areas, screening is becoming more accepted and its value more apparent.

Screening greatly reduces the entrance of common greenhouse pests such as thrips, aphids and whiteflies, as well as some less common pests such as tarnished plant bugs and European corn borers, which can become major pest problems when pesticide use is reduced (e.g. in biological control programs). Benefits of using insect screening have been demonstrated in Israel and California. In Ontario, growers who have installed screens have reported that pest levels and pesticide use are reduced and effectiveness of pest control measures (especially biological control) improved.

The most important consideration for a grower wishing to screen a greenhouse is to determine which pests need to be excluded. The size of the pest determines the mesh size of the screen that is needed. Large mesh sizes of the style normally found in household screens are inadequate for excluding most major greenhouse pests; however, they can be useful in keeping out occasional larger pests such as tarnished plant bugs and lepidopteran (moth) pests. For smaller insects such as thrips, screens must be made of a very fine mesh for total exclusion. In cases with multiple pests of concern, mesh size should exclude the smallest of these pests.

Reduction of airflow by screening is a major concern of growers. It can lead to the greenhouse overheating and stress on the fans (in the case of fan-ventilated greenhouses), which must work harder to pull the same amount of air through the vents that are, in effect, partially blocked. Reduced ventilation is a valid concern, but it can be addressed by increasing the surface area of the vent. In many situations this has been completed successfully by building a screened framework around the vent opening. The goal is to ensure that the final surface area of the vents provides sufficient air exchange to allow adequate cooling of the greenhouse. There are several methods available to determine the required increase in surface area of the vents for any given greenhouse, but factors such as screen mesh size, fan capacity and static pressure drop (the difference in air pressure between inside and outside the greenhouse when the fans are running) are important. Although there are software programs available to assist with these calculations, they can be complicated and are generally best left to screening manufacturers.

The small mesh size means that the screens are very prone to blockage with dust and other deposits, especially in the summer. Clean the screens regularly as blockage reduces airflow through the screens and may contribute to excessively high temperatures in the greenhouse. It is also important to incorporate easy access in the design of the screens to facilitate their cleaning. Wash screens from the inside with a high-pressure hose. Do not do this when the fans are operating, because the water will block the pore openings and completely stop airflow, leading to overheating of the greenhouse.

The effectiveness of the screen depends on its ability to exclude flying insects. Repair tears or holes as soon as possible to avoid pest entry. Small tears can be simply repaired by gluing a piece of screening over the hole.

The cost of screening will depend on several factors: the final screening design, the increase in surface area needed to maintain adequate ventilation, the cost of the screening material, whether roof vents or side vents are to be screened, frequency of replacement, frequency of cleaning, etc. The biggest variable is the difference in cost between installing screens in a fan-ventilated, side-vented greenhouse or a passively vented greenhouse with roof vents. Nevertheless, reports from growers who have installed screens over side vents in fan-ventilated greenhouses suggest a rapid payback from reduced pesticide costs and improved pest management.

For more information, see OMAFRA Factsheet, *Screening Greenhouses for Insect Exclusion,* Order No. 00-021.

Other physical controls

Yellow sticky tape can provide additional control of flying insect pests. It works on the same principle as the sticky cards used for monitoring. String tape along beds or benches or hang it vertically within the crop to provide significant supplementary control in conjunction with other control methods.

Biological Control

Biological control is the use of living organisms such as insects, mites, nematodes, fungi and bacteria to control pests such as insects, mites and diseases. Biological control requires very different approaches for vegetables and floriculture. While it is has been widely used in greenhouse vegetable crops for many years, it is only since the mid-2000s that it has become the predominant control strategy in ornamentals. Table 4-3. *Biocontrol Agents for Principal Greenhouse Pests,* on page 45, lists the commercially available natural enemies used for insect and mite management in greenhouse floriculture.

Biological control involves more than just the release of parasites or predators. To be successful, plan at least several months in advance. Follow these steps when considering the use of biological control:

1. Develop a list of resources to help with the program (this may include producers and/or suppliers of biocontrol agents, other growers, extension specialists, researchers or consultants). Attend courses, seminars and workshops; read magazines and newsletters; use the Internet to find out as much as possible about biocontrol. Determine which pests to control and which are the most appropriate natural enemies to use.

2. If possible, start in a small and isolated part of the greenhouse to focus more closely on the area being used, and to gain some experience with biological control before applying the concepts on a larger area. After reaching a level of comfort with biological control, expand the use of natural enemies to include other areas of the operation.

3. If possible, screen the area to be used. Movement into the greenhouse of pests from outside is unpredictable from year to year. Large numbers can swamp a biocontrol program and make it difficult for the natural enemies to maintain control. With screening, growers need only be concerned about the pests inside the greenhouse. See *Screening,* on page 43.

4. Ensure that all staff is aware of the biological control program and why it is being used. They are in the greenhouse every day performing routine crop

management tasks and with proper training can recognize problems at a very early stage.

5. Many registered pesticides can have long-term (2–3 months) residual impact and can prevent the establishment of natural enemies. Check pesticide spray records for the previous several months. If such pesticides have been used, wait the appropriate length of time before starting. Use products with less residual impact to control pests and diseases during this period. Side effects of many pesticides on different biocontrol agents are available in hard copy from the biocontrol suppliers or on the Internet from Biobest *(www.biobest.be)* or Koppert *(www.koppert.com)*.

6. Work with the supplier to learn how to check incoming biocontrol agents and determine if they are alive and well. The quality of natural enemies produced by the major insectaries is excellent, but problems can occasionally arise in shipping. Suppliers need to know about any problems in quality so the causes can be identified and corrected.

7. Follow instructions in storing and releasing the natural enemies. Many can be stored for only a short period of time under fairly specific conditions.

8. Monitor the populations of natural enemies and the progress of the biocontrol program. This is as important as monitoring the pest populations.

   - Use sticky cards to monitor flying insects, especially the parasitic wasps. Be aware however, that some natural enemies (e.g. *Eretmocerus* for whitefly control) are highly attracted to yellow, and too many sticky cards may be detrimental to the program.

   - Check the impact of the natural enemy on the pest. For example, parasitism of whitefly by *Encarsia* and aphids by *Aphidius* parasitic wasps is easily checked.

   - Visually inspect the crop for natural enemies such as predatory mites, which do not fly. Inspect the crop especially in areas of highest pest numbers.

Table 4–3. Biocontrol Agents for Principal Greenhouse Pests

Pest	Biocontrol Agent
Whitefly *(Trialeurodes vaporariorum* and/ or *Bemisia argentifolii, Bemisia tabaci)*	*Encarsia formosa*[1] *Eretmocerus eremicus*[1] *Eretmocerus mundus*[1] *Amblyseius swirskii*[2] *Delphastus pusillus*[2] *Dicyphus hesperus*[2] *Beauveria bassiana*[3]
Spider mite *(Tetranychus urticae)*	*Phytoseiulus persimilis*[2] *Amblyseius fallacis*[2] *Amblyseius californicus*[2] *Amblyseius andersoni*[2] *Feltiella acarisuga*[2] *Stethorus punctillum*[2]
Western flower thrips *(Frankliniella occidentalis)*	*Amblyseius cucumeris*[2] *Amblyseius swirskii*[2] *Amblyseius degenerans*[2] *Orius* spp.[2] *Hypoaspis* spp.[2] *Atheta coriaria*[2] Nematodes – *Steinernema feltiae* *Beauveria bassiana*[3]
Aphids, including: green peach aphid *(Myzus persicae)*, melon aphid *(Aphis gossypii)*, foxglove aphid *(Aulacorthum solani)*, potato aphid *(Macrosiphum euphorbiae)*	*Aphidius* spp.[1] *Aphelinus abdominalis*[1] *Aphidoletes aphidimyza*[2] Lady beetles *(Harmonia* and *Hippodamia)*[2] Lacewings[2] *Beauveria bassiana*[3]
Fungus gnat *(Bradysia* and *Corynoptera* spp.)	*Hypoaspis* spp.[2] Nematodes — *Steinernema* spp. *Atheta coriaria*[2]
Leafminer *(Liriomyza trifolii)*	*Diglyphus isaea*[1] *Dacnusa sibirica*[1]

[1] Parasitoid: Usually requires only one host for completion of development, often killing it by living on or in its body.

[2] Predator: Feeds on its prey (pest) by catching it, but otherwise lives independently of it. It must consume more than one individual to reach maturity.

[3] Microbial agent

   - Regularly monitor pests to determine if populations are decreasing.

9. Use compatible pesticides if necessary. Such pesticides should be identified prior to starting a program so they are available and can be used if necessary. Contact your biocontrol suppliers for more information on pesticide compatibility.

10. Be patient. It takes time and experience to understand and implement an effective system of biocontrol. Ask others with experience if the program is not progressing as expected.

Commercially produced biocontrol agents are available for all the major greenhouse insect and mite pests, but not yet for diseases. For more details about the implementation of biological control or about supplies of parasites/predators, consult an OMAFRA greenhouse pest management specialist, crop specialist or an industry consultant.

Use caution when using pesticides with biocontrols, since most pesticides are harmful to natural enemies. Application of just one harmful pesticide can prevent any further use of biocontrol agents for an extended period of time. Contact your biocontrol supplier for more information or look on the Internet for the side-effects lists on the Biobest website *(www.biobest.be)* or Koppert website *(www.koppert.com)*.

Chemical Control

Pesticides will remain an important component of greenhouse pest management programs, however growers should carefully monitor their use for the reasons previously noted with regard to biocontrol, and as part of a resistance management program.

Resistance

Pests can develop resistance to any pesticide if it is used incorrectly or too often. Although there are benefits from new product registrations, do not simply wait for the latest advance in pesticide chemistry. The long-term problems presented by pesticide resistance far outweigh the short-term gains of a new product if it is used incorrectly.

Resistance is the evolutionary adaptation of a population to survive a pesticide dose that is lethal to most of its individuals. It is an inherited trait, which is passed on to future generations. While resistance does not develop within an individual during its lifetime, it usually exists naturally in some individuals in a population, but at very low frequencies (too low to be measured or noticeable). The frequency of resistance increases when pesticide exposure kills susceptible individuals, while allowing successively greater numbers of resistant individuals to survive and reproduce, passing on their resistance to their offspring.

Resistance management programs aim to reduce the pressure applied to pest populations by pesticides. Use diverse control methods to reduce the need for pesticides. There are several ways to do this, mirroring the approach of IPM programs. Growers who use an IPM program, including good monitoring techniques and cultural, biological, and physical controls, are practising resistance management at the same time.

Note that when pesticides are used in an IPM program, the rate at which resistance develops increases if one class of pesticides (e.g. organophosphorus, synthetic pyrethroid, carbamate) is used for a prolonged period. The speed at which resistance develops depends on a number of factors. It may be a short as 1–2 years or could take place over a period of 10 years or more depending on:

- the pest being controlled
- the pesticide being used
- the pesticide history of the greenhouse
- how often the pesticide is applied
- the introduction of pests from other facilities
- the resistance management strategies that are in place

To slow the rate of resistance development, rotate pesticide classes every few weeks or for a period equal to the generation time of the pest being controlled. See Chapter 9, *Pesticide Application, Toxicity and Activity,* on page 93, for pesticide classes.

Pesticides must be used responsibly and as part of a broader resistance management program. For more information on pesticide application, see Chapter 9, *Pesticide Application, Toxicity and Activity,* on page 93.

5. Major Insect and Mite Pests

Biosecurity

Biosecurity is a process to protect a geographic area or individual facility from pests and diseases. It includes reducing the risk of introducing new pests and diseases and eradicating or effectively managing the spread of those that have already arrived. As a producer, taking common sense precautions to prevent pests and diseases from entering the farm is a worthwhile investment. In the context of greenhouse floriculture, this should entail good sanitation and IPM practices as described in Chapter 4, *Integrated Insect and Mite Management,* on page 39 and Chapter 7, *Integrated Disease Management,* on page 69. The development of a biosecurity policy for visitors entering the facility also plays an important role in reducing the potential for the introduction and establishment of new pests and diseases.

Quarantine pest problems

This chapter describes the most common insect and mite problems in greenhouse ornamental production. However, it is important to understand that some of the most destructive pests are much less frequently found, although their impact can be devastating when they are. Some of these pests are known to be a potential risk and are regulated as quarantine pests by the Canadian Food Inspection Agency (CFIA). A quarantine pest is "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2004)." Other pests may have no known potential for damage until they occur, at which time CFIA will determine the risk they present. If regulated pests are found, the law *(Plant Protection Act)* demands that it be reported to CFIA, who will then decide what action must be taken to address the problem. Although this action can have serious financial impacts on individual growers, it is important to the industry that growers report suspected problems. Failure to do so could threaten the export of ornamental plants to countries such as the United States. Known quarantine pests likely to affect greenhouse floriculture production are noted in Chapter 6, *Occasional Pests,* on page 61 and Chapter 8, *Major Greenhouse Diseases,* on page 79. For more information on regulated pests and diseases, visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA office. See Appendix D. *Other Contacts,* on page 131.

Thrips

For more information on thrips, see OMAFRA Factsheets *Management of Thrips in Greenhouse Crops,* Order No. 03-075, and *Biology of Thrips in Greenhouse Crops,* Order No. 03-077.

Description and life history

Thrips are tiny, slender, agile insects that are about 1.5–2 mm in length when fully developed. Adults vary in colour from dark brown or black to yellow or straw-brown. Immature thrips are usually white or yellow with red eyes. Several thrips species, including eastern flower thrips, onion thrips and western flower thrips (WFT) are found in the greenhouse.

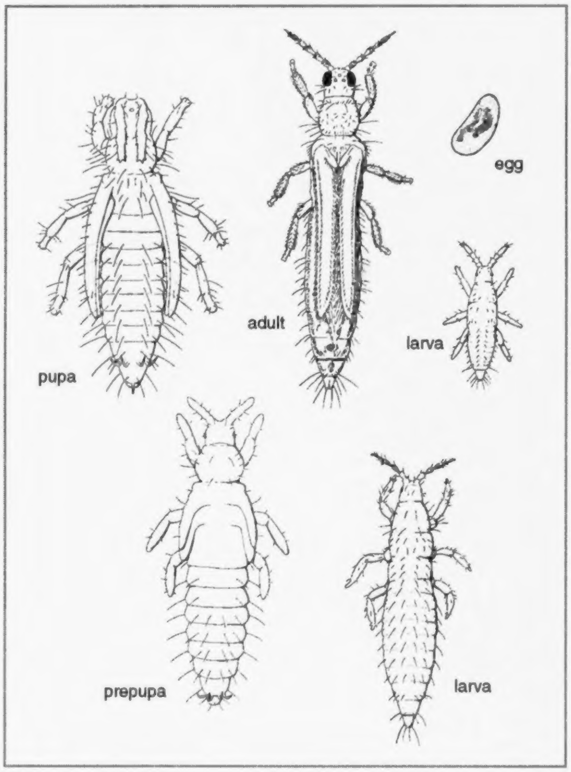
All thrips have a similar life cycle (see Figure 5-1. *Western Flower Thrips,* on page 48). The adult female lays tiny white eggs inside the leaf tissue. The eggs hatch in 5–7 days and the white larvae emerge to feed on the leaves and petals. Before becoming adults, they pass through two larval stages, a prepupal stage and a pupal stage (in the soil or on the plant). Adults can live up to seven weeks. A new generation may occur every 20–35 days, depending on the temperature.

Damage

Piercing/sucking mouthparts cause white streaked areas on leaves or translucent spots on flower petals. Feeding is characterized by tiny, black, fecal deposits on leaf surfaces. Adult females can also damage fruit quality in crops such as tomato, including patio tomatoes, by laying eggs in the fruit. Small whitish "ghost-spots" appear where eggs are laid, which causes uneven fruit ripening.

Thrips also rapidly develop pesticide resistance. They can carry impatiens necrotic spot virus or tomato spotted wilt virus (INSV/TSWV), which can devastate many common greenhouse crops. Proper diagnosis is essential, as these viruses have a wide host range and produce a wide variety of symptoms. Control of INSV/TSWV is difficult, involving thrips population management, removal of infected plants and good weed control inside and outside the greenhouse. Use indicator plants such as petunia or fava bean for early detection of INSV/TSWV.

Figure 5–1. Western Flower Thrips



Control strategies

Employ a regular monitoring program using yellow or blue (both very attractive colours to WFT) sticky cards and regular crop inspection.

Larval and adult stages of the thrips can be detected by tapping buds or flowers over a sheet of white paper and checking the thrips that fall.

Biological control

A number of biological control agents are available for thrips: the predatory mites *Amblyseius cucumeris, Amblyseius swirskii, Amblyseius degenerans* and *Hypoaspis,* the predatory bug *Orius insidiosus,* and the predatory rove beetle *Atheta coriaria.*

Use more than one in combination to gain the best control. Introduce them when pest levels are low, using high enough introduction rates to achieve success.

Amblyseius cucumeris

This buff-coloured predator feeds mainly on the first larval stage of thrips.

Amblyseius cucumeris (A. cucumeris) is usually shipped to growers in a mixture that includes bran and bran mites. The bran provides food for the bran mites, which are themselves food for the predatory mites. The bran/mite mixture is available in small sachets or in containers from which the mixture is sprinkled directly onto the crop. The sachets serve as small rearing units from which predatory mites emerge over several weeks.

Always examine the bran mixture prior to use. It should not be mouldy or smell of ammonia, and live predatory and bran mites should be visible. Healthy predatory mites move rapidly, whereas bran mites move more slowly. Hang sachets in sheltered positions to minimize dehydration of the bag contents. Rates of application of this predator vary with crop and level of thrips infestation. Contact the biological control supplier, consultant or OMAFRA IPM specialist for suggested rates.

Amblyseius swirskii

This predatory mite is very similar in size and appearance to *A. cucumeris.* It is sold in the same types of formulations (bulk mixtures and slow release sachets) and feeds on the same life stages of the thrips. It is reported to be more effective than *A. cucumeris,* especially on crops that produce pollen such as ornamental peppers. However, some early experience in ornamental crops such as gerbera is also promising. *Amblyseius swirskii* is also effective against other pests such as whitefly.

Contact the biological control supplier, consultant or OMAFRA IPM specialist for suggested rates.

Amblyseius degenerans

This predator differs from *A. cucumeris* in its appearance and ability to tolerate less humid conditions. It is dark, very agile and reproduces very well on pollen.

It can be reared on castor bean plants, which can be release points for the predator within the greenhouse. It performs best in situations where it has a pollen source (e.g. greenhouse pepper including ornamental pepper) to encourage establishment. Because of this, it is unlikely to be the best option for most floricultural crops where product is shipped before significant amounts of pollen are produced.

Hypoaspis

This soil-dwelling mite provides additional thrips control by feeding on pupae in the crop media. For more details, see *Fungus Gnats and Shoreflies,* on page 55.

Orius insidiosus

The minute pirate bug, *Orius insidiosus,* is a winged predator that consumes all mobile stages of thrips. Adults are black with white and cream markings on the wings. The youngest nymphs are yellow and the oldest are a dark mahogany brown.

Orius insidiosus also feeds on pollen, spider mites, aphids, whiteflies, moth eggs and young caterpillars; however, its preferred food source is thrips.

Pirate bugs are sensitive to day length. Do not release them in greenhouses before mid-March unless a minimum of 13 hours of light is available, such as when supplemental lighting is used.

Atheta coriaria

This soil-dwelling beetle was originally developed for control of fungus gnats and shoreflies, but also feeds on thrips pupae in the soil. For more information, see *Fungus Gnats and Shoreflies,* on page 55.

Chemical Control

Chemical control of WFT can be difficult. They tolerate most pesticides and feed either deep within the flower head or on developing leaves. This makes them a difficult target for insecticides, so thorough coverage is essential. General recommendations regarding pesticide use for thrips control are as follows:

- At the action threshold (when thrips population levels dictate spraying to prevent economically damaging numbers from appearing), spray 4–5 days apart for three consecutive applications.

- Follow resistance management guidelines on the label.

- Rotate chemical classes and use a single chemical class only for the duration of the thrips' life cycle. This generally means using a different class every 2–3 weeks depending on time of year. Generation times are longer at cooler temperatures.

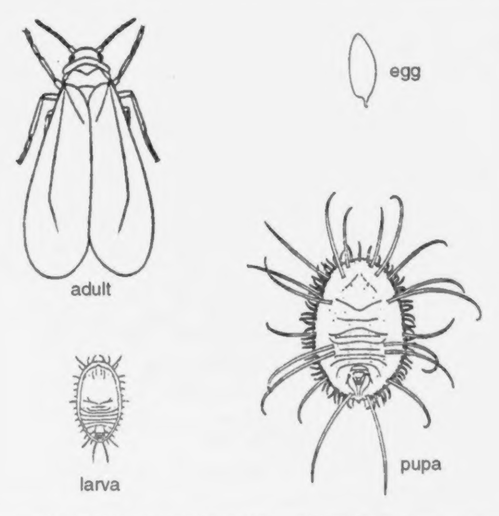
- When there is a limited number of effective products, use sparingly and only at critical times of the year or crop. Use IPM strategies to reduce pesticide use and the potential for resistance development.

- Apply pesticides in early morning and late afternoon, when flight activity of thrips is at a peak. This increases exposure of the thrips to the pesticides.

Whiteflies

For more information on whiteflies, see OMAFRA Factsheet *Biology of Whiteflies in Greenhouse Crops,* Order No. 03-065, and *Management of Whiteflies in Greenhouse Crops,* Order No. 03-067.

Figure 5–2. Greenhouse Whitefly



Description and life history

Adult whiteflies are small, white, winged insects about 1.5–2 mm long. They lay eggs (which are too small to be seen clearly without a microscope) on the underside of the youngest leaves. A female whitefly might lay up to 300 eggs during her lifetime and can live up to two months. The nymphs or crawlers hatch in 5–10 days, are flat and scale-like and crawl around for a short while before becoming immobile.

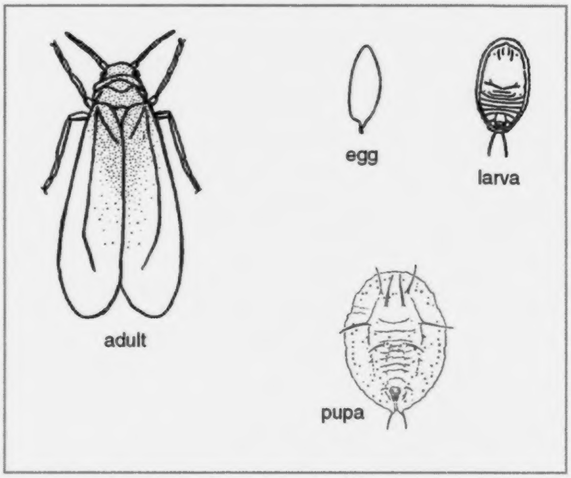
Adults emerge after three nymphal stages and one pupal stage. Old pupal skins and adults may be found on the underside of lower leaves, which may have symptoms of wilt. On average, the whitefly completes its life cycle in 35 days at 18°C and in 18 days at 30°C. Whiteflies have no special overwintering stage and can usually survive if plant life is available.

Species of whiteflies

Two species of whiteflies concern growers in Ontario: the greenhouse whitefly (GWF) and the silverleaf whitefly (SLWF). They are depicted in Figure 5-2. *Greenhouse Whitefly,* on page 49 and Figure 5-3. *Silverleaf Whitefly,* on this page. The GWF and SLWF adults look very similar, but with some differences:

- The SLWF is slightly smaller than GWF and its body is more yellow.
- At rest, SLWF holds its wings tent-like above its body, while the GWF holds them flatter and more parallel to the surface on which it is resting.
- The major diagnostic differences between GWF and SLWF appear in the pupal stages. The GWF pupa is raised off the leaf surface and is surrounded by a fringe of hairs, while the SLWF pupa sits flat on the leaf and does not have a fringe. These features are best seen with a microscope.
- SLWF fly in a more direct manner, while the GWF assume a more haphazard flight pattern.
- In Ontario, SLWF is most commonly found on poinsettia, although it can also establish on other crops.
- Two biotypes of SLWF have been found in North America. The B biotype has been a pest in greenhouses since the mid-to-late 1980s and is found most often on poinsettia. The Q biotype is Mediterranean in origin and was found for the first time in North America on poinsettia in 2004. It is reported to rapidly develop resistance to pesticides. It is also reported to have a wider host range than the B biotype and to be better as a vector of a range of plant viruses.

Figure 5–3. Silverleaf Whitefly



Damage

Piercing/sucking mouthparts allow whiteflies to remove sap from the plant, reducing plant vigour.

Whiteflies excrete large amounts of a sugary substance called honeydew. Honeydew promotes the growth of a black sooty mould fungus on leaf and fruit surfaces, reducing photosynthesis and fruit quality respectively. The sooty mould itself does not damage the plants.

The SLWF is reported to transmit over 60 viruses and the GWF has been associated with the spread of beet pseudo-yellows virus in cucumbers.

Control strategies

Implement a routine monitoring program using yellow sticky cards and plant inspections.

Identify the whitefly species present on the crop.

Consider the use of trap plants (plants that are more attractive to whiteflies than the main crop) as an early detection tool or to attract whiteflies to a more localized area for easier control. Plants such as eggplant and tomato may be useful for this purpose, especially for GWF; however, be aware that other pest problems can develop on plants used in this way and if neglected, they can become more of a problem than a solution.

React promptly when whitefly adults are observed on either cards or terminal leaves.

Maintain good weed control inside and outside the greenhouse.

Biological control

Three parasitic wasps – *Encarsia formosa, Eretmocerus mundus* and *Eretmocerus eremicus* – are commercially available for whitefly control. *Encarsia formosa* is more effective against GWF, but also provides some control against SLWF. *Eretmocerus mundus* is specific and very effective against SLWF. *Eretmocerus eremicus* is more effective against SLWF but can also provide good control of GWF. The predatory mite *Amblyseius swirskii* is reported to be very effective against all species of whiteflies, as well as thrips. A small, black beetle called *Delphastus pusillus* is also available commercially, but is likely only effective where there are heavy populations of whitefly (a situation that most growers would want to control more quickly with pesticides).

Good sanitation, weed control and low whitefly numbers at the outset are essential for successful biological control of whitefly.

Encarsia formosa

About 0.6 mm long, adult wasps kill whiteflies either by laying eggs into the immature stages or scales (mostly the third and fourth larval stages) or by directly feeding on the young whitefly nymphs. Adult *Encarsia* can live for a few days to a month depending on the temperature. Females lay 50–350 eggs in their lifetime. GWF turns black 10–14 days after being parasitized. On average, the adult wasp emerges two weeks later. When the adult develops fully, it cuts an opening in the top portion of the black scale before emerging. Parasitized SLWF turn tan-brown and are less easily noticed. For biological control of SLWF, *Eretmocerus* offers a better alternative.

To use *Encarsia* successfully:

- Avoid pesticides with long residual effects for at least three months before the initial release. Refer to Side-effects Lists provided by biocontrol suppliers.

- Monitor the crop for whitefly presence at all production stages and follow population trends to place and time *Encarsia* releases more accurately.

- Introduce *Encarsia* at the first sign of whitefly, or preventatively before whiteflies are detected. If whiteflies are present before the release of *Encarsia*, reduce populations with a low-residual pesticide.

- Do not use *Encarsia* between December and February without adjusting light and temperature conditions to suit the parasite. Nevertheless, these months are the most difficult time to establish *Encarsia* in the greenhouse.

- Distribute *Encarsia* in shaded parts of the plant where they are protected from direct sunlight.

- Distribute cards relatively evenly but place more in areas where whiteflies have been observed. Achieve more distribution points by purchasing cards with fewer parasitized scales per card.

- During deleafing or pruning operations in vegetable crops, such as tomato, do not remove leaves with immature parasitized scales. Such removal slows build-up of *Encarsia* numbers and parasitism rate.

- Continue introducing *Encarsia* until approximately 80% of the scales on older leaves are black. During warmer months when whiteflies migrate into the greenhouses, maintain or increase introductions.

Eretmocerus mundus and Eretmocerus eremicus

Adults are about 0.6 mm long and yellow in colour. They lay eggs under the whitefly larvae, usually the second or third stage. This wasp has a sex ratio of 1:1 (male:female). This is different from *Encarsia*, where all individuals are female. The effectiveness of this wasp is due to both parasitism and host feeding by the adult. The parasitized whitefly pupa is a yellowish-brownish colour (for both GWF and SLWF). *E. mundus* is specific to *Bemisia* (SLWF), whereas *E. eremicus* will feed on both whitefly species.

Amblyseius swirskii

This predatory mite is very similar in size and appearance to the thrips predator *A. cucumeris*. It also feeds on thrips, but unlike *A. cucumeris*, it is also a very effective whitefly predator. Permits for its import to Canada were only obtained in the spring of 2006, so experience with its use is still limited.

Amblyseius swirskii feeds on whitefly eggs and crawlers. As a result, it is very compatible with the parasitic wasps used for whitefly control, which target later life stages. It is sold in bulk mixtures or slow release sachets.

It is reported to be very effective, especially on crops that produce pollen. Early experience in ornamental crops such as gerbera is promising.

Contact the biological control supplier, consultant or OMAFRA IPM specialist for suggested rates.

Delphastus pusillus

Delphastus is a predatory beetle. Both adult and larval *Delphastus* feed on whiteflies, particularly on the eggs and nymphs. *Delphastus* are reported to avoid parasitized scales, feeding primarily on the non-parasitized scales. This behaviour makes *Delphastus* compatible with *Encarsia.* Use these beetles to supplement the activity of *Encarsia* in reducing whitefly populations. Adult *Delphastus* live for 6–9 weeks. They are reported to require a minimum diet of 10 whitefly eggs per day to reproduce.

Physical control

Sticky traps

Use yellow sticky traps in various forms to trap large numbers of adult whiteflies. Large, yellow sticky cards can be placed in "hot spots" or alternatively, hang yellow sticky tape between posts or above plant rows. Such tapes will also trap fungus gnats, shoreflies, *Aphidius* spp. and *Encarsia,* especially under low whitefly populations. Be careful when using large quantities of sticky tape in conjunction with parasitoids, especially *Eretmocerus,* which is highly attracted to yellow.

Vacuuming

Hand vacuum adults in "hot spots" to rapidly remove adult whiteflies.

Insect barriers

Install fine screens over vents and doorways to significantly reduce migration of outdoor populations into greenhouses. Where whiteflies move in from adjacent field crops (e.g. field tomato) in large numbers at certain times of the year (e.g. during harvest), consider screening as a first line of defence.

Chemical control

Rational and judicious pesticide use requires a regular monitoring program to determine whitefly population levels and the need to spray, rotating chemical classes and incorporating non-chemical control strategies. Whiteflies have developed resistance to many pesticides. Careful use will extend the effective life of pesticides while delaying the build-up of resistance.

When using a systemic insecticide such as Intercept, ensure that it is applied correctly. The root system should be well developed and the plant actively growing. If the plant is to be pinched, apply the product 10–14 days afterwards. Limit watering for a week after application to reduce the amount of leachate; Intercept is very water-soluble and will be easily leached from the pot.

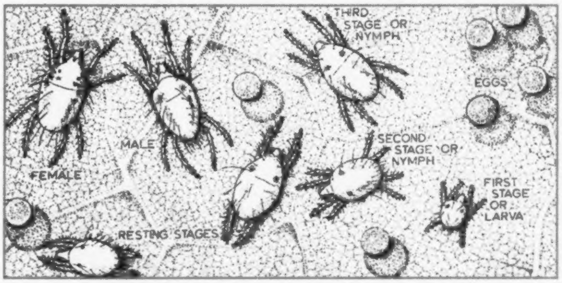
Two-Spotted Spider Mite

Description and life history

The two-spotted spider mite (TSSM) attacks many greenhouse crops. The eight-legged female adult is approximately 0.5 mm long with a rounded abdomen. The male is distinguished from the female by its smaller, narrower body and pointed abdomen. Adults range from pale yellow to orange to brown. The overwintering or diapausing stage is reddish-orange. Day lengths of 12 hours and less, decreasing temperatures and a deteriorating food source will induce diapause in spider mites. During diapause, spider mites can tolerate very low temperatures. A short spell of heating is not sufficient to break its diapause.

Close examination of leaf undersurfaces will show the mites to be miniscule moving dots. The two dark spots on the body of TSSM are the gut contents showing through the transparent body. After mating, each female mite lays approximately six pearly white eggs a day. Over an average lifetime, a female lays 100 or more eggs on the undersurface of foliage. Newly hatched mites pass through the typical six-legged larval stage and eight-legged protonymph and deutonymph stages. The last of these is an immobile

Figure 5–4. Two-Spotted Spider Mite



resting stage, very tolerant of miticides. The life cycle from egg to adult ranges from 23 days at 15°C to just four days at 32°C (Figure 5-4. *Two-Spotted Spider Mite,* on page 52). Development is fastest under hot, dry conditions.

Damage

All active stages of the TSSM feed by piercing the lower epidermis of the leaf with sucking mouthparts. The feeding injury starts as a yellow "stippling." As mite numbers increase, the entire leaf appears stippled or light-coloured on the upper surface. Very heavily infested leaves become yellow and brittle, with obvious webbing on the leaves.

Some plants (e.g. hibiscus) exhibit a toxic response to TSSM feeding, with leaves yellowing and dropping from the plant even at quite low mite population densities. If infestations proceed without control measures, plants may be killed.

Mite populations seem to explode at certain times of the year, since the life cycle varies considerably with temperature. Other factors, such as humidity, plant nutrition and cultivar are important and at times can be used to help reduce mite outbreaks.

Control strategies

In ornamental crops, make regular crop inspections to detect early infestations before mites build up. Pay particular attention to susceptible varieties and crops. In crops such as rose, inspect both upper and lower canopies.

For vegetable crops, conduct a proper cleanup at the end of the crop to reduce initial infestations in the crop that follows. Do this just before the overwintering or diapausing phase of the spider mites, since the diapausing mites hibernate in the ground, hollow stems, pipe fittings, cracks and crevices during the fall and winter. The mites become active again during late winter and early spring. The red mite stage is generally pesticide tolerant and not as readily fed upon by predators. When the red diapausing mites are detected, use soap sprays on lightly infested leaves and remove and destroy more heavily infested leaves.

Biological control

Control spider mites biologically using the predatory mite *Phytoseiulus persimilis.* Other predatory mites can be used against this pest, including some strains that are high-temperature tolerant or pesticide resistant. For example, the predatory mite *Amblyseius californicus* is reported to better tolerate dry conditions, while *Amblyseius fallacis* is resistant to some pesticides. Many Ontario growers have had good success with these predators.

Phytoseiulus persimilis

Phytoseiulus persimilis is about the same size as TSSM but is pale salmon to bright orange and pear-shaped. It does not have two spots and moves more rapidly on long legs. It feeds on spider mites and does not diapause.

Without spider mites, the predators die. This means new spider mite infestations require new introductions of the predator. Adult predators feed on about seven adults or 15–20 eggs per day. At 20°C, *P. persimilis* almost doubles the reproductive rate of TSSM. Control with *P. persimilis* is best between 20°C and 26°C. At temperatures above 30°C and humidities under 60%, predators do not thrive and seek cooler, more protected areas lower in the crop canopy. In contrast, TSSM thrive under these conditions.

Predators are available commercially either mixed with vermiculite or on bean leaves. With either carrier, treat infested plants at first sign of damage. Try to place a few predators onto every infested leaf. Before releasing the predators, ensure that they are alive and very active.

Cultural control

Misting plants and raising the humidity will help suppress spider mite populations. For example, at 20°C and 36% relative humidity, a female TSSM will lay about seven eggs per day, while at 95% humidity, approximately 30% fewer eggs are laid.

Chemical control

Because of their great reproductive potential, TSSM easily develop pesticide resistance. To effectively manage this pest using pesticides, observe these guidelines:

- Direct sprays to the underside of leaves where spider mites usually congregate.

- Good coverage is essential to good control, particularly when using contact miticides such as Dyno-Mite, Floramite and Shuttle.

- The webs in areas of high mite density can protect the mites and the eggs within and beneath the web. In such cases, use higher spray pressures to penetrate the web.

- Use non-chemical control options as much as possible to minimize the development of pesticide resistance.

Aphids

For more information on aphids, see OMAFRA Factsheet *Aphids in Greenhouse Crops,* Order No. 06-081.

Description and life history

Aphids are small (2–3 mm), soft-bodied insects with long legs and antennae. A pair of tube-like structures called cornicles projects from the posterior end. Several species may infest greenhouses, with colour patterns ranging between black, grey, red, yellow and green. The species most commonly found in greenhouse crops are the green peach aphid *(Myzus persicae),* the cotton or melon aphid *(Aphis gossypii),* the foxglove aphid *(Aulacorthum solani)* and the potato aphid *(Macrosiphum euphorbiae).*

The green peach aphid was the predominant aphid species in Ontario until the early 1990s, when the melon aphid started to become much more common. In the late 1990s, the incidence of potato aphid and foxglove aphid in Ontario greenhouses increased and currently the foxglove aphid is one of the most common aphid pests.

Adult aphids are predominantly wingless, although winged adults can develop under conditions of high population density. This adaptation serves as a dispersal mechanism, allowing aphids to move into a greenhouse from outside or to spread rapidly within a greenhouse.

In a greenhouse situation, all aphids are female and give birth to live young. These offspring can reproduce within 7–10 days (see Figure 5-5. *Green Peach Aphid,* on this page). One aphid can give birth to 60–100 young over a 20-day period. Aphids can rapidly achieve very large populations.

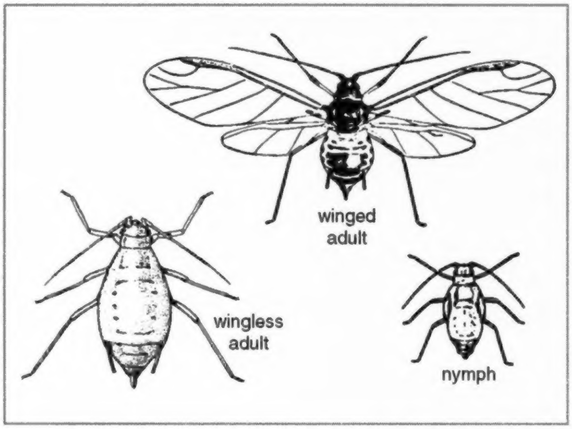
Damage

Aphids pierce plant tissue with their mouthparts and suck out the sap, causing deformed leaves and flowers. Distortion of the growing points of plants is particularly common with the foxglove aphid.

Aphids moult through a number of different stages before they become adults. The cast-off skins they leave behind each time they moult are an indicator of their presence.

They excrete a sugary, sticky substance called honeydew, which promotes the development of black sooty mould fungus. Some aphids can transmit plant virus diseases, such as cucumber mosaic virus in cucumber crops.

Figure 5–5. Green Peach Aphid



Control strategies

When monitoring for aphids, catch winged adults on yellow sticky cards.

For wingless aphids, inspect new foliage carefully and regularly to prevent large infestations.

Spot treating isolated infestations can prevent their spread to the rest of the greenhouse.

When infestations occur in the blossom stage, smokes may be more effective and less phytotoxic to plants.

Biological control

Several types of biological control agents are readily available: the predatory midge *Aphidoletes aphidimyza,* the parasitic wasp *Aphidius* spp., and lady beetles *(Hippodamia convergens* and *Harmonia axyridis). Aphidoletes* and lady beetles are usually used to supplement the activity of *Aphidius* and reduce the aphid populations in "hot spot" areas.

Aphidoletes aphidimyza

In the adult stage, *A. aphidimyza* resemble small mosquitoes or fungus gnats. Females lay up to 200 eggs in their lifetime. Eggs are laid close to aphid colonies, so the orange larvae have a readily available food source on hatching.

Larvae usually hatch after 2–3 days. After 7–14 days in the larval stage, they drop to the floor to pupate. The pupal stage usually lasts about two weeks. Adult *A. aphidimyza* feed on honeydew and larvae can kill 3–50 aphids per day. Under natural day lengths, *A. aphidimyza* enter diapause between September and March; they are not effective during this period.

Aphidius spp.

This parasitic wasp does not enter diapause and can be effective all year. During summer, other parasitic wasp species can parasitize *Aphidius,* reducing their impact on aphid populations. Optimum conditions for *Aphidius* are 18–25°C and 80% relative humidity. *Aphidius* completes its development from egg to adult in about 10 days at 25°C and 14 days at 21°C.

Several species of *Aphidius* are commercially available. *Aphidius matricariae* can parasitize about 40 aphid species, including the green peach aphid. It occurs naturally in Ontario and it is not unusual to find natural infestations in greenhouses where pesticide use has been reduced. *Aphidius colemani* is effective against both the melon and green peach aphids, but not against the foxglove or potato aphids. *Aphidius ervi* is the best choice against the foxglove and potato aphids.

Lady beetles (Harmonia axyridis and Hippodamia convergens)

Both adult and larval lady beetles feed on aphids and can eat large numbers during the course of their lifetime. Lady beetles enter diapause under short-day conditions. When day lengths are suitable, lady beetles must feed on aphids to maintain egg production. Eggs are orange and torpedo-shaped. They are laid in circular clusters on the underside of leaves and hatch in 2–5 days.

The larval stage lasts for approximately three weeks, after which they pupate. Adults emerge from pupal cases after 3–5 days. To increase the percentage of lady beetles remaining in the greenhouse, sprinkle a sweet liquid (e.g. diluted pop) over the beetles and release them in late evening. The sweet liquid provides an immediate energy and water source.

Harmonia lady beetles (also known as the multicoloured Asian lady beetle) have become a pest in their own right in southern Ontario. Large populations have established outside, which has resulted in them becoming a nuisance pest for homeowners when they enter houses looking for overwintering sites. But more importantly, they are also a pest of grapes grown for wine, with adult beetles infesting ripe grape bunches and contaminating wine production. Their establishment in the outdoor Ontario environment has nothing to do with their use as a biocontrol agent in greenhouses, but rather as a result of their introduction into North America from Asia many years ago. However, the poor public perception of these insects has resulted in fewer commercial insectaries producing and selling them, even though they can be very effective.

Fungus Gnats and Shoreflies

For more information on fungus gnats and shoreflies, see OMAFRA Factsheet *Fungus Gnats and Shoreflies in Greenhouse Crops,* Order No. 06-079.

Description and life history

The grey to black adult fly is about 3–4 mm long with long legs, thread-like antennae and large compound eyes that meet above the base of the antennae. The adult is a weak flier, frequently observed resting on the media surface. Each female lives about 10 days and lays about 150 white, oval eggs in the organic matter of the media. Eggs hatch in 2–7 days, depending on the temperature, producing white larvae that are 4–6 mm long.

The larvae have 12 abdominal segments and a distinctive shiny black head. The larvae pupate in the soil and remain immobile for 4–6 days, after which adult flies emerge. As with most insects, fungus gnats become more active and reproduce more quickly at warmer temperatures. The life cycle (see Figure 5-6. *Dark-Winged Fungus Gnats,* on this page) can be completed in 21 days at 24°C, compared with 38 days at 16°C.

Shoreflies, another common greenhouse pest, are often confused with fungus gnats. The adults are stouter than fungus gnats, stronger fliers and have four clear spots on the wings. Like fungus gnats, shorefly larvae (see Figure 5-7. *Shoreflies,* on this page) live in soil, but lack the distinctive black head capsule. They prefer moister conditions than fungus gnats and are often found in wet areas under benches with both adults and larvae feeding on algae.

Shoreflies are not usually a direct threat to greenhouse crops but can feed on roots in recirculating systems. Shorefly control requires controlling algae, either directly (by applying chemicals) or indirectly (by reducing moisture necessary for algal growth or reducing the high light levels the algae need, perhaps by the use of blackout skirts around benches).

Damage

Although fungus gnats generally feed on decaying organic matter in the soil, they can also feed on the young roots of plants. This is especially true when gnat populations are high.

Fungus gnats have occasionally been observed feeding on the youngest shoots of cucumbers. Root feeding by fungus gnats makes a plant susceptible to root diseases such as *Pythium* root rot. Fungus gnats and shoreflies have also been implicated in the spread of disease-causing organisms such as *Pythium, Fusarium, Verticillium* and *Rhizoctonia.*

Control strategies

Sanitation inside the greenhouse and in the surrounding outside area is very important.

Avoid overwatering and maintain proper drainage to prevent water puddling – fungus gnats and shoreflies thrive in moist conditions.

Biological control

Biological control agents include a predatory mite, *Hypoaspis,* a predatory beetle, *Atheta coriaria* and a parasitic nematode, *Steinernema feltiae.*

Figure 5-6. Dark-Winged Fungus Gnats

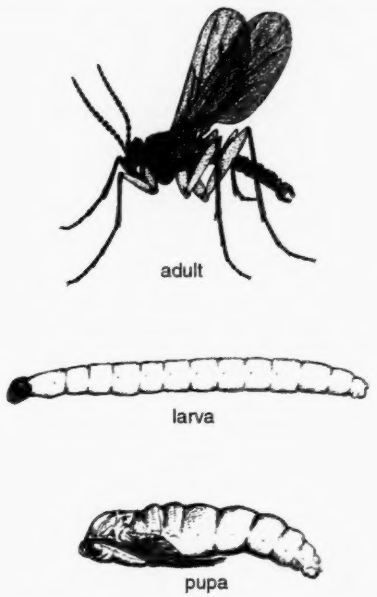
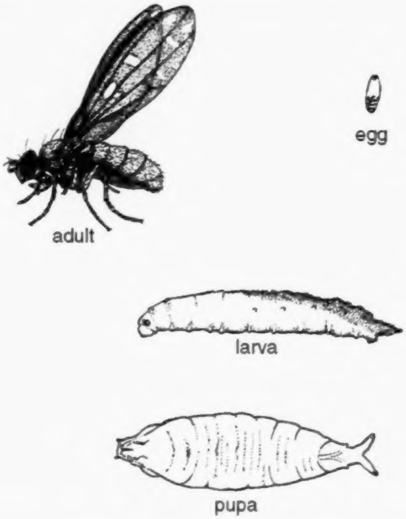


Figure 5-7. Shoreflies



Hypoaspis

Hypoaspis is a soil-dwelling, brown mite that feeds on fungus gnat eggs and larvae, algae, thrips pupae, springtails, nematodes, and larvae of various flies and beetles. *Hypoaspis* is a hardy mite that can live approximately 24 days without food. It is not affected by low light conditions and has a life cycle of about 9–11 days under greenhouse conditions.

It is found mainly on the surface or in the top 1 cm of the plant media. It works best when applied to the media just after plants are potted up or vegetable seedlings are planted out. *Hypoaspis* is most effective if introduced when fungus gnat populations are still low or non-existent.

Atheta coriaria
The rove beetle *Atheta coriaria* is a small, black, soil-dwelling beetle about 3–4 mm long. It is very active and both the adult and the three larval stages feed on fungus gnats (eggs and larvae), shoreflies (eggs and larvae) and thrips (pupae). It is produced and sold commercially, but is also naturally occurring and often found in greenhouses where pesticide use is reduced. It should be used in a similar fashion to *Hypoaspis* – introduced into the crop early to control soil-dwelling pests.

Nematodes
The nematode *Steinernema feltiae* is best used under higher population conditions. Nematodes enter the body openings of fungus gnat larvae and then release bacteria, which multiply and kill the larvae. Because nematodes are believed to be unable to multiply within the bodies of fungus gnat larvae, use several consecutive nematode applications to achieve control. Nematodes do not control shoreflies.

To use nematodes successfully:

- Use cool water to mix the spray solution. Nematodes have limited energy reserves and these will be depleted more quickly at warmer temperatures.
- Shake or agitate nematode stock solutions regularly to incorporate oxygen into the water and to prevent nematodes from settling to the bottom of the tank. A commercial pond air pump or aquarium bubbler can perform both functions.
- Use the solution as soon as possible after mixing.
- Media temperatures should be 16–30°C.
- Never expose nematode suspensions to direct sunlight, which destroys the bacteria within the bodies of the nematodes.
- Plant media should be pH 3–8.
- Check the compatibility or residual activity of pesticides before applying to media that have been, or will be, treated with nematodes.

Chemical control

Soil drenches can effectively control the larvae.

Leafminers

Description and life history

Two main species of leafminers affect Ontario growers: the vegetable leafminer *(Liriomyza sativae)* and the serpentine leafminer *(Liriomyza trifolii)*. A third species, the pea leafminer *(Liriomyza huidobrensis)*, which is a major pest in other parts of the world, has also been found in Ontario. Although the serpentine leafminer can complete development on tomato and cucumber, it prefers chrysanthemum, gerbera and gypsophila. Conversely, vegetable leafminer prefers tomato, cucumber and celery but will attack chrysanthemum and other plants in the absence of its preferred hosts. The pea leafminer has a wider host range and can also move into field-grown crops, including vegetable crops such as cole crops, lettuce and celery. The three species of leafminer are similar in appearance and biology.

The adult leafminer is small (approximately 3 mm long), with black and yellow markings on the head and thorax. Adults become active at sunrise. Females feed on soft, succulent leaves by piercing the surface with their ovipositor, then lapping the liquid exuding from the leaf. The leaf wounds made by the female are called "stipples" and are easily visible as distinctive raised small circular scars on the leaf surface.

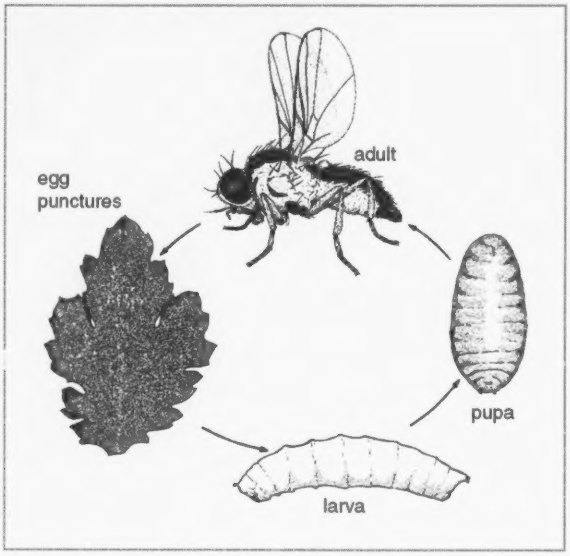
Female flies begin laying eggs 12–24 hours after emerging from the pupa. They lay about 250 eggs during their approximately 30-day lifespan. Eggs are laid in about one out of seven leaf punctures (or stipples). The optimal temperature for leafminer development is 30°C. At temperatures above or below 30°C, egg production by the female declines considerably. After 2–4 days, eggs hatch and the larvae begin feeding (or mining) in the leaf tissue.

The larvae mature in 4–7 days in summer, then cut a hole in the leaf surface and drop to the ground.

Pupation takes place within a few hours, in the plant media or on plastic sheeting (where used). Pupation can also occur on the leaves. The pupal stage may last 5–10 days in the summer and up to 90 days during periods of low temperature (10–12°C) and scarce food supply. This may account for the winter survival of leaf miners around the inside perimeter of the greenhouse, though no adult leafminers are evident. From the pupae, a new generation of adult flies emerges.

There is considerable overlapping of stages of the insect life cycle within any greenhouse. The complete life cycle of the leafminer (Figure 5-8. *Leafminer,* on this page) can be 14 days at 30°C, 24 days at 20°C and 65 days at 14°C.

Figure 5–8. Leafminer



Damage

Leafminer feeding may indirectly affect yield by reducing the plant's photosynthetic area and damaging water-conducting vessels (causing leaf desiccation and leaf drop).

Feeding damage by leafminers mars the appearance of ornamental crops, significantly reducing their economic value.

Control strategies

Inspect all new plant material entering the greenhouse.

Destroy infested seedlings, cuttings and plant parts or those showing evidence of stippling.

If growing in ground beds, steam-sterilize the entire greenhouse floor between crops.

Monitor the crop for pests with yellow sticky cards and regular crop inspections.

Eliminate weeds inside and outside the greenhouse. Weeds such as lamb's-quarters, chickweed, dandelion, plantain, common mallow and nightshade are good hosts for leafminers.

Do not over-fertilize the crop – excess nitrogen levels can increase leafminer problems.

Bag and remove detached leaves from the greenhouse as soon as possible. Leafminer larvae can complete their development in leaves even after they are removed from the plant.

Biological control

Biological control agents include the parasitic wasps *Diglyphus isaea* and *Dacnusa sibirica. Diglyphus* is likely to be a better choice in summer, when its numbers may be supplemented by naturally occurring populations migrating into the greenhouse from outside. *Dacnusa* is reported to perform better than *Diglyphus* during the winter.

Diglyphus isaea

Diglyphus is a small, black wasp with a metallic green sheen and short antennae. After locating a mine, the female first paralyzes the larva, then inserts an egg through the leaf, placing it near the leafminer. It may deposit up to five eggs in a mine in this manner. The larva that hatches is initially colourless, then becomes yellow-brown and finally turquoise. Development time from egg to adult is about 11 days at 25°C. This is generally shorter than that of both the leafminer and *Dacnusa*.

Diglyphus can parasitize leafminers already parasitized by *Dacnusa*. It becomes the dominant species during summer, when warm conditions favour activity. Presence of short mines indicates *Diglyphus* activity, as the paralyzed leafminer stops feeding immediately. The presence of *Diglyphus* larvae can be detected by holding leafminer infested leaves up to the light and examining with a hand lens.

Dacnusa sibirica

The adult is a small, black wasp that differs from *Diglyphus* in having long, flexible antennae and lacking the metallic green sheen. Unlike *Diglyphus,* a female *Dacnusa* inserts an egg directly into the body of the leafminer. Each female lives for about two weeks, during which time she may lay up to 90 eggs.

Eggs hatch within four days and the larvae mature within the leafminer pupae. Development time from egg to adult is about two weeks at 22°C. All *Dacnusa* development takes place within the leafminer's body; therefore, assessing parasitism is difficult.

Chemical control

Leafminers easily develop insecticide resistance.

Ensure good pesticide coverage of the crop.

Rotate pesticide classes every 2–3 weeks on crops for which registered pesticides exist. Currently, pesticide registrations exist only for ornamental crops.

Line drawings of insects in this section are used with permission from *Insect and Related Pests of Flowers and Foliage Plants* (1994). North Carolina Co-operative Extension Service, Ed. J. R. Baker.

6. Occasional Pests

Ants

Ants are easily recognized by their elbowed antennae (bent in the shape of an elbow) and narrow waists. They range from 1.5–6 mm long.

Ants are attracted to sweet substances and therefore may be a problem in greenhouses where insect feeding has produced honeydew or where flowers have nectaries. They can also jeopardize biocontrol programs against aphids by protecting the aphids against attacks from natural enemies. Treat all ant trails or nests located in or near the greenhouse. Flooding nests with insecticidal soap and using household boric acid baits can provide some control.

Beetles

Beetles comprise the largest order of insects, but very few are pests of greenhouse ornamental crops. There are two, however, that are important to note.

The Japanese beetle (JB) is a quarantine insect pest, which is found in parts of Ontario. The adult beetle is brown with a metallic green sheen and measures about 1 cm long. It has a number of distinctive white tufts at the edge of its wing covers, along each side of its body. The beetle larvae live in the soil and are C-shaped with brown heads and three pairs of legs. The mature larvae are about 2.5 cm in length. The quarantine status of this beetle means that its movement and that of infested plants, soil and related matter are regulated to help prevent further spread into uninfested areas. While not a major pest of greenhouse crops in Ontario, in some situations it can have an impact on both domestic and export movement of plant material, depending on the crops being grown and the facility in which they are grown. Some crops such as grasses and sedges are of particular concern, but growers of any greenhouse crops who ship to regions without JB (or that have a lower infestation ranking than Ontario) must be certified by CFIA. Contact your local CFIA office (see Appendix D. *Other Contacts*, on page 131) for more information.

The second beetle of importance is the black vine weevil (BVW). Weevils (or snout beetles) have a hard body with a snout and elbowed antennae. Adult BVW do not fly. They are dull brown to black, about 9 mm long with fine ridges along the back. The larvae are legless grubs, white with reddish-brown heads and are found among roots of various bedding plants.

Adults actively lay eggs in June and the larvae feed on the roots for the rest of the season. The larvae will attack a wide range of plants including rose, geranium, fern, gardenia, kalanchoe and rhododendron. Although the adult does not fly, it can move to new plantings easily.

Use control measures in late May and June. Inspecting the roots of all material introduced to the greenhouse may prevent an infestation.

Caterpillars/Moths

Several different insects have caterpillar stages that damage greenhouse crops. These include leaf rollers, armyworms, cutworms, loopers, fruitworms, hornworms and leaf tier and stalk borers. The adult moths of these caterpillars are often attracted to greenhouse lights in the summer and will lay eggs that hatch into the caterpillar pest.

Duponchelia fovealis is a small, nondescript, greyish-brown moth with a wide host range that includes many greenhouse ornamental crops. It is Mediterranean in origin but has become established in greenhouse production in many northern European countries. Between 2005 and 2008, a number of Ontario greenhouses experienced outbreaks of this moth. While at one time it was regulated by CFIA as a quarantine pest, that status has changed and it is now simply considered an economic pest (the same status as other common greenhouse pests). It is however, listed as "actionable" by the USA, and if found in shipments, will result in rejection or destruction of the load. Host crops include rose, begonia, cyclamen, gerbera, kalanchoe, anthurium and poinsettia. Infestations and damage can be minimized using a combination of biological control and chemical control.

Armyworms and cutworms feed directly on plant foliage and may cause considerable damage. Both insects are dark brown or grey with longitudinal stripes. Cutworms burrow into the soil during the day and come out to feed at night. Use insecticides recommended for caterpillars to bring armyworm and cutworm infestations under control.

Cabbage loopers commonly attack certain greenhouse crops, such as alstroemeria, between July and September. Cabbage loopers are green with faint white longitudinal body stripes.

Stalk borers bore into plant stems, making them more difficult to control.

Another damaging borer, the European corn borer, can be a serious pest of greenhouse vegetables and a potential pest of some greenhouse ornamental crops, infesting many fruits before being detected. They normally begin infestations in spring around May to early June. There are two generations of this borer in southwestern Ontario and one generation elsewhere in Ontario.

Pheromone traps can be used to detect certain moth species, and light traps can be used to monitor many species.

If you detect these pests early, begin control before the small caterpillars start feeding. Screened vents help prevent the entry of moths and a good inside/outside weed control program will reduce potential infestation sites. Apply a bacterial insecticide containing *Bacillus thuringiensis kurstaki* (Btk) for control of loopers and most leaf-eating caterpillars that are not miners.

Grasshoppers

Grasshoppers are easily recognizable and occasionally invade greenhouses. They will feed on almost any vegetation and, in large numbers, can destroy plants. Grass and weeds near greenhouses may allow a grasshopper infestation to occur, usually in late summer and fall.

Mealybugs

Two distinct groups of mealybugs are found in greenhouses. The more common foliage-feeding mealybugs are white, wax-covered, scale-like insects with piercing mouthparts that remove plant sap.

Mealybugs produce large amounts of honeydew. The females (1–3 mm long) lay large numbers of eggs in masses of wax. Active immature mealybugs called crawlers hatch from these eggs in 5–10 days. The nymphs mature into reproductive adults in 6–8 weeks.

Damage is caused in a variety of ways: the removal of plant sap, the growth of black, sooty mould fungus on the honeydew and the unsightly appearance of the waxy secretions.

Mealybugs are serious greenhouse pests because the crawlers spread rapidly and exist under bud scales and within leaf axils. Males, present in low numbers, are small, winged insects.

The second group is the root-feeding or subterranean mealybugs which are found within masses of wax, on the roots of wilting or yellowing plants. These insects are very similar to those described above but secrete less wax over their bodies.

Carefully inspect all plant materials entering the greenhouse for the presence of mealybugs. The crawler stage of all mealybugs may spread to other plants through contaminated equipment or via water leaching through pots. Most infestations result from introduced contaminated material.

Biological control agents for this pest include the Australian lady beetle, *Cryptolaemus montrouzieri,* the common lady beetle, *Hippodamia convergens,* and a parasitic wasp, *Leptomastix dactylopii.*

Midges

These small (1 mm), delicate flies lay eggs in the stems, leaves or flower buds of ornamental plants. The larvae burrow into plant tissue, causing swellings of stems, galls on leaves or collapse of buds.

Swede midge affects Brassica crops. It is primarily a pest of field vegetables, however Brassica bedding plants (cabbages, broccoli, etc.) and ornamental cabbages and kale are also affected. The adult is a small fly (1.5–2 mm long) which lays its eggs in the growing point of the plant. The larvae feed on the developing leaves resulting in distortion of the growing point and providing an entry point for disease. Swede midge was first found in southern Ontario in 2000. It is now present in most areas of Ontario and Quebec and has also been found in Nova Scotia and Saskatchewan. Originally a quarantine pest in both Canada and the USA, it was deregulated in 2009 and is now treated in the same way as other economic pests.

The rose midge is an occasional problem for Ontario rose growers as it can quickly cause serious losses, however it is an infrequent pest in greenhouses. Flower buds bend or become distorted, then turn brown and die. The rose midge is most abundant during the hot summer months, when it enters greenhouses from infestations on outdoor roses. Eggs hatch in approximately two days; larvae mature in 5–7 days and drop to the soil to pupate in another 5–6 days. The adult midge then emerges and lives for only a couple of days. Pesticide sprays for the adult stage are ineffective. For rose midge, use a foliar spray of the systemic Orthene to control larvae in the base of the buds.

Mites

Cyclamen mite/broad mite

Cyclamen mites and broad mites are microscopic in size. They are no larger than 0.25 mm long and cannot be seen without magnification. The female's hind pair of legs is thread-like, while those of the male are pincer-like.

The pale brown female mite deposits approximately 100 eggs, 80% of them female, around the crown of the plant or along the midrib of unfolded leaves. The mites develop through the six-legged larval stage and quiescent nymphal stage with eight legs, similar to the two-spotted spider mite. The life cycle from egg to adult is about two weeks but varies depending on the temperature.

Distorted leaf tissue and/or small blasted or twisted flower buds and flowers are usually the first damage symptoms. Foliage will often show purplish areas. The cyclamen mites feed around the crowns of plants or in the flower buds. Cyclamen is usually the most seriously injured, but many foliage and bedding plants, as well as other potted crops, can be attacked.

Tomato russet mites

The adult mite is 0.2 mm long and 0.05 mm wide. Because of its small size, the mite is not noticed on plants until it reaches damaging levels. At that time the stems, leaves and fruit appear beige or bronze as a result of the high mite population density.

Russet mites appear to thrive under dry conditions. The life cycle lasts about six days at 27°C and 30% relative humidity (RH). Females can lay approximately 16 eggs during their lifetime, which is about three weeks. Russet mites feed first on stems, then on leaves.

Damage symptoms include yellowing, curling, and wilting of leaves, flower abortion, and bronzed, cracked fruit. If uncontrolled, the tomato russet mite will eventually kill the plant.

Alternative hosts for this pest include nightshade, petunia and several other species of the tomato family.

No early detection techniques exist for this mite. Once established in a crop, they easily spread by hands, equipment and clothing.

There are no current recommendations for biological control. Work to date indicates that two predatory mites, *Amblyseius fallacis* and *Typhlodromus occidentalis,* are potential biocontrol agents.

Scale Insects

Scales are minute, wingless insects up to 3 mm long. They have piercing/sucking mouthparts and an oval or hemispherical body shape. Scales secrete a characteristic waxy or scale-like covering over their bodies. Males, which are rare, have wings.

Most scales are females that lay hundreds of eggs under their immobile scale. When these eggs hatch, the small crawlers migrate to new feeding sites. Damage is caused by the removal of sap from plants, which results in yellowing, wilting, stunting and distortion of plants.

Several species have been identified on greenhouse ornamentals in recent years, mainly due to the increased quantities of foliar stock being imported from tropical areas. Many newer introductions of fern, palm and ivy plants are susceptible to scale infestations.

To help control scale, quarantine, check and treat or destroy infested material.

Biological control agents for soft and armoured scales include two small lady beetles, *Chilocorus nigritus* and *Lindorus lophanthae.* A small parasitic wasp, *Metaphycus helvolus,* has been reported to help manage several species of soft scales. Another wasp, *Aphytis melinus,* can be used for several species of armoured scales.

Ivy scale and greedy scale

These scales are similar in appearance, pale and circular with a prominent yellowish nipple in the centre. Both attack a wide variety of greenhouse plants such as ivy, palm, ficus and fuchsia.

Fern scale

The shield of this scale resembles an oyster shell. It is brown with a lighter terminal nipple and is usually found on ferns and other foliage.

Brown soft scale

Female scales are flat, brown and pliable. They have a wide host range and produce large amounts of honeydew that promote the development of black, sooty mould fungus.

Hemispherical scale

The scale covering on this species is very convex, brown and shiny. Ferns are a favourite host.

Slugs and Snails

Slugs are dark grey, soft-bodied creatures, 1.3–10 cm long. They glide over plants leaving a shiny trail. Slugs eat the foliage of most greenhouse plants, shredding the leaves and sometimes completely destroying a plant.

Snails are similar in colour and appearance to slugs, except that a snail bears a noticeable shell. The shell varies in colour and markings, and may be 1.3–5 cm in diameter. Snails are particularly injurious to seedlings. They eat holes in the flowers and leaves of many plants, leaving them shiny and tattered.

Individual snails may lay up to 100 eggs, depending on the species. Slugs lay fewer eggs that may remain unhatched for long periods under dry conditions. They hatch upon return of moist conditions.

Both slugs and snails need a damp environment and fairly humid air to survive. They avoid the sun and emerge primarily at night or on cloudy days. During the day, slugs hide under boards and rocks or in other damp, shady places. If the air or substrate is dry, a snail can pull its entire body into its shell and remain dormant for up to four years.

Indirect control strategies for these organisms should focus on reducing their favoured habitat.

Remove boards, bricks, etc. that are in contact with the ground or arrange them to permit proper air circulation around and under them.

Maintain a plant density that permits sunshine to penetrate to the ground level, provides good air circulation and allows the plant media to dry.

Where a low plant density is inappropriate, use a ground cover unattractive to snails (e.g. rough-cut cedar chips or crushed eggshells). Sawdust and diatomaceous earth are effective barriers if kept dry.

Various devices can trap or attract slugs and snails for subsequent destruction. Set traps using beer or a mixture of water and commercial yeast as an attractant. Crush snails or slugs and cover with an inverted flower pot, or invert grapefruit halves to attract slugs and snails.

Chemical controls involve pesticides formulated as baits. Metaldehyde is toxic and must be inaccessible to children and pets. Prolonged use of baits is likely to produce a local bait-resistant population.

Sowbugs/Pillbugs

Sowbugs and pillbugs have grey, flattened, oval bodies up to 13 mm long with seven pairs of legs. Sowbugs have two small, tail-like structures that the pillbugs lack.

They are both small decomposers but occasionally feed on roots and tender plant parts, causing seedling damage. They feed at night and hide during the day, preferring dark, moist areas with abundant organic matter.

Sterilizing soil and eliminating decaying plant material and moist areas will help prevent a build-up of these pests. Many strategies used for snail and slug control also suppress sowbug/pillbug populations.

Springtails

Springtails are tiny, wingless insects 2–6 mm long. They range in colour from white, grey or yellow to red, orange, purple, brown or mottled hues.

They are usually found on the surface of moist soil, in pots or within the soil, and have a spring-like apparatus at the end of the abdomen that allows them to spring into the air.

Most springtails are scavengers, feeding on decaying organic matter, algae or fungi. Because they do not usually feed on living plant material, chemical controls are rarely necessary.

Striped Cucumber Beetle

Striped cucumber beetles are yellow-green beetles, approximately 6 mm long, with three longitudinal stripes. These beetles and their relative, the spotted cucumber beetle, carry the bacteria *Erwinia tracheiphila,* which causes bacterial wilt in cucumbers and related species such as melons and squash which could be an issue for bedding plant growers with vegetable transplants.

Striped adult cucumber beetles overwinter outdoors under old leaves, old logs or garbage. They emerge the following spring, mate, feed for several weeks, and then lay orange-yellow eggs in the soil at the base of plants.

Larvae usually hatch in 10 days, then feed on the roots of plants for 2–6 weeks. Fully-grown larvae are about 9 mm long. Pupation takes place in the soil and adults emerge after approximately one week. There is only one generation per year in Ontario.

The adult beetles damage plants by chewing on leaves, stems and fruits. However, the greatest damage comes from the wilt-causing bacteria they often carry, which can survive the winter in their gut. In the spring, the beetles inoculate plants with the disease as they feed on the plant tissue.

There is no control for the wilt once a plant is infected. Inoculated leaves generally wilt within 5–6 days, and the plant dies within two weeks. Striped cucumber beetles can also transmit cucumber mosaic virus.

The best control comes from insect barriers installed over all greenhouse openings to exclude the adult beetles.

Symphylans

Symphylans are found under stones, in rotting wood and in moist soil high in decaying organic matter. They are small white creatures resembling centipedes, with long, slender, white bodies (1–5 mm long), long antennae and 10–12 pairs of legs (centipedes have 15 pairs of legs).

While centipedes are beneficial predators that prey on many insects, symphylans can feed on the roots of plants. On many crops, damage appears as tiny black marks on the roots where a hemispherical piece of tissue has been scooped out. Injured roots become stubby and the plant becomes stunted. Damage caused by symphylans to roots and root hairs provides entry points for root-rotting diseases.

Steam sterilization of soil or heating of soil by solarization can help to reduce populations.

Tarnished Plant Bug

These bugs are about 6 mm long, yellow-brown, with piercing mouthparts. The adults and their green nymphs feed on many crop and weed species. They can be serious pests to greenhouse crops such as chrysanthemum, gerbera, cucumber and pepper.

Eggs are inserted into plant tissue and the small nymphs complete their life cycle in about four weeks. They damage new growth by causing foliage distortion and dead or distorted flower buds. They are most active during the summer and fall, and may gain access to the greenhouses from surrounding weedy areas.

Tarnished plant bugs tend to appear in crops where pesticide use is minimal. Eliminating weeds that may serve as spring/summer hosts or overwintering sites will lower overall populations. Screening vents will help control this pest.

Tomato Pinworm

The tomato pinworm (TPW) is a semi-tropical pest that can infest tomato crops in Ontario, and as such could be an issue for bedding plant growers producing vegetable transplants. It inflicts damage by feeding on tomato leaves and fruit. Other suitable hosts for TPW are potatoes and eggplant. Weeds such as nightshade and its relatives may also serve as hosts.

The adult is a small, light-brown moth about 6 mm long. It is generally more active at night, laying most of its eggs on younger leaves during the first few nights of activity. Newly hatched larvae walk on the leaf surface for a very short time before entering the leaf to start mining.

There are four larval stages, with the first two spent in the leaf. The third and fourth stages may be found between two leaves knitted together, in a leaf that has been folded over or inside fruits. Larvae characteristically enter fruits just beneath the calyx.

Mature larvae may either remain on the plant or drop to the ground to pupate. On the ground, pupation usually occurs within the top 15 cm of soil. Tomato pinworms do not diapause. Their development continues year-round, slowing during cold weather periods. Development time from egg to adult usually ranges between 28–70 days, depending on temperature. The life cycle is completed in 28 days at 24°C, and can be as short as 19 days at 30°C.

For control:

- Inspect all seedlings for larval feeding damage.
- Destroy all old infested plants and any debris from infested crops.
- Monitor for the presence of tomato pinworm with pheromone or light traps and by inspecting crops regularly. Note that pheromone traps attract only male tomato pinworm, whereas light traps attract both sexes of tomato pinworm and many other insect species.
- Hand-pick damaged leaves and destroy larvae within the mines.
- Destroy weeds and stray tomato seedlings inside and around the greenhouse.
- Install insect barriers over vents.

Vertebrate Pests

Rats and mice may be very destructive in the greenhouse. They feed on almost any food source and can cause damage by gnawing and burrowing.

Norway rats and field mice are the most common vertebrate inhabitants of greenhouses. Baits containing rodenticides such as chlorophacinone, diphacinone, warfarin and zinc phosphide can offer some control. The first three chemicals are anticoagulants and multiple doses are usually required. Zinc phosphide is not an anticoagulant and is more acutely toxic – a single dose can kill. Ensure that the toxic baits are placed in covered stations where they cannot be accessed by pets and children.

To minimize the development of rodenticide resistance, particularly to the anticoagulants, always use a variety of control measures. For example:

- Store all potential food material in tight-fitting containers.
- Use many traps where there are signs of activity, placing one trap every 2–3 m along walls.
- Set traps at right angles to the wall, with the bait and trigger facing the wall.
- Handle traps with gloves to avoid contaminating them with human smells.
- Try different baits. Suggested baits include peanut butter mixed with oats, raisins, gumdrops, any other sticky food material and cotton, which provides nesting material.

- Maintain several female cats, which tend to be more predacious than males, as biological control agents.

Root Nematodes

Plant parasitic nematodes are small (less than 1 mm long), worm-like organisms that live in the root media. They are broadly divided into two groups: ectoparasites, which attack plants externally and endoparasites, which spend at least part of their life cycle within the plant tissue.

All parasitic nematodes have stylets through which they inject saliva into plant tissue. The saliva causes most of the damage, causing necrosis or the proliferation of giant cells that produce galls.

Nematodes cause damage mainly by reducing the ability of plants to absorb water and nutrients. Above-ground symptoms of nematode damage include weakened plants that wilt in the sun, yellow or pale green leaves and stunted fruit or flowers.

Where nematicides are used between crops, nematode infestations often recur because of insufficient penetration of the chemicals into the lower soil levels. Soils treated in this manner should always be properly aerated to avoid subsequent plant damage.

Root-lesion nematode, *Pratylenchus penetrans* (Cobb)

This endoparasitic nematode is native to Ontario soils and can attack many floral and vegetable crops. All stages are thread-like and invisible to the naked eye.

This nematode invades the outer layers of young roots, causing small brown-to-black elliptical lesions that merge to discolour the roots and subsequently kill them.

Northern root-knot nematode, *Meloidogyne hapla* (Chitwood)

This is another endoparasitic nematode native to Ontario soils. It attacks almost all types of vegetable crops and many floral crops, particularly rose, African violet and geranium. Early larval stages are thread-like and invisible, while later stages and adults are peanut- to pearl-shaped and just visible when dissected from roots.

This nematode invades roots and causes swellings, knots or galls and excessive root proliferation. Infested roots do not necessarily become discoloured unless attacked by bacteria and fungi.

Dagger nematode, *Xiphinema diversicaudatum* (Micoletzky)

This ectoparasitic nematode is not native to Ontario and was introduced into greenhouses on plant stocks. Dagger nematodes prefer plants with woody roots and are more frequently associated with crops such as strawberry, grape and rose. The nematode survives in the root crotches of the understock.

One of the largest nematodes attacking plants, this 6 mm, thread-like roundworm can be seen on the roots if examined carefully. It feeds on young roots in the soil, causing galls similar to root-knot galls but somewhat larger. These galls are actually curved swellings in the root tip area, accentuated with the necrosis and shrivelling of roots above the galls.

Pin nematode, *Paratylenchus projectus* (Jenkins)

This nematode is native to Ontario and can attack many floral and vegetable greenhouse crops, especially rose. All stages of pin nematode are thread-like and invisible to the naked eye. This species is active in both fine-textured (clay) and coarse-textured (sandy) soils.

The pin nematode does not enter roots, but feeds at root tips by probing root hairs and surface cells. No specific root symptoms, such as galls or lesions, appear. Plants infested with this nematode can appear stunted and unthrifty.

Southern root-knot nematode, *Meloidogyne incognita* (Kofoid and White)

This endoparasitic nematode is not native to Ontario but has become persistent in the protected greenhouse environment. It cannot survive outdoors during winter. It is a problem on tomato and cucumber, but can also attack several floral and foliage crops.

Root damage and symptoms differ from those of the northern root-knot nematode. Plants damaged by the southern root-knot nematode have larger galls and lack fine root growths from the galls. Leaves may show phosphorus deficiency (purpling) on the underside or downward curling of leaf edges.

Foliar Nematodes

There are a few nematodes that attack plant foliage. Symptoms caused by leaf-feeding nematodes are similar to those of several diseases and nutrient deficiencies.

Strawberry bud nematode, *Aphelenchoides fragariae* (Ritzema Bos)

This nematode is not native to Ontario but was introduced on plant stock. It is primarily a problem on begonia, but can also attack other greenhouse ornamentals. Invisible and thread-like, it moves in moisture films on stems and leaves.

The nematode penetrates leaves through the stomata and feeds in the inner layers of the leaf, causing small brown spots with water-soaked margins on the underside of leaves. The spots subsequently enlarge and merge, turn dark brown and become visible on the upper surface. Finally, the entire leaf is affected.

Chrysanthemum nematode, *Aphelenchoides ritzemabosi* (Shwartz)

This nematode is not native to Ontario but was introduced on plant stock. It is almost identical to the strawberry bud nematode and moves and infests plants in the same manner.

Early symptoms include dark-brown spots on the underside of leaves and vein discolouration. Infested leaves eventually turn brown or black, forming distinct wedge-shaped areas between the veins. Finally, the leaves dry, shrivel and hang down along the stems.

Cultural controls for nematodes

The following are cultural control measures for minimizing nematode problems:

- Use soil-free media or steam-sterilized media.
- Ensure that transplants are vigorous and free of root galls or lesions.
- Use nematode-resistant or nematode-tolerant cultivars, or nematode-resistant rootstocks, where applicable.
- In soil-grown vegetable crops (e.g. tomato and cucumber), mound peat or sterile soil at the plant bases to stimulate adventitious root growth and help extend the productive life of the plants.

7. Integrated Disease Management

Integrated disease management (IDM) is a disease control philosophy that uses all available management strategies to maintain disease pressures below an economic injury threshold. It does not advocate a routine chemical application program to prevent disease, but promotes the integration of cultural, physical, biological and chemical control strategies. The routine application of fungicides for insurance purposes is no longer appropriate, as it does not focus the proper attention on the real problem and can lead to resistance and potential environmental issues.

The basic objectives of any IDM program should be to achieve at least the following:

- reduce the possibility of introducing diseases into the crop
- avoid creating conditions suitable for disease establishment and spread

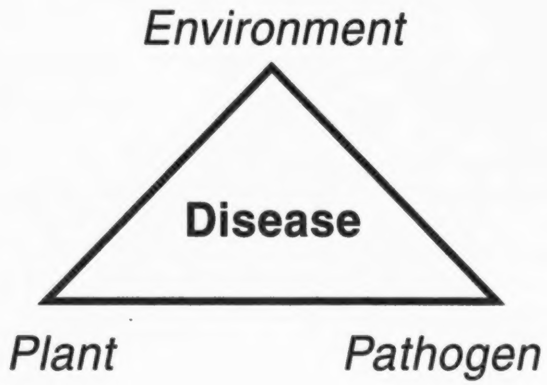
A sound disease management program integrates a few universal principles and concepts into the overall production system for that particular crop. It is important to understand the concepts of disease control and the strategies developed from them, to make modifications appropriate for a particular greenhouse or crop situation. A disease control program involves more than a fungicide application, which too often addresses the symptoms but not the problem.

The Disease-Triangle Concept

Figure 7-1. *The Disease Triangle,* on this page, shows the importance of the three factors necessary for disease development:

- a pathogen or disease-causing organism (e.g. a fungus, virus or a bacterium)
- a susceptible plant for the pathogen to infect
- a suitable environment in which the first two will interact

Figure 7-1. The Disease Triangle



For example, *Thielaviopsis basicola* will attack the bedding plant Vinca when air and media temperatures are cool (15–17°C), but rarely at temperatures above 21–22°C. However, this pathogen will attack pansy when temperatures are above 25–26°C, the media pH is high (above 6.5) and the sanitation is generally poor.

The plant environment includes the soil or growing media in which the roots grow and the above-ground environment or air where the shoots, leaves and flowers are produced.

Soil or media environment characteristics that must be considered include:

- pH
- nutrient levels and their balance
- EC
- moisture-holding capacity
- media texture to allow good drainage
- oxygen content

Aerial environment characteristics that must be considered include:

- light levels
- temperature
- air movement
- relative humidity (RH)
- air quality

Six General Principles of Plant Disease Control

Exclusion

Preventing pathogens from becoming established in the greenhouse is a primary aspect of disease control. For example, geranium propagators use this principle each year when they purchase new virus-indexed/pathogen-free cuttings for stock plant production. This minimizes the potential for fungal and bacterial infections such as geranium rust or bacterial wilt.

Growers who use soil or compost in their media pasteurize the material to eliminate soil-borne pathogens. The use of new, clean pots, cell packs and flats prevents any potential carryover disease inoculum from infecting newly planted crops.

Avoidance

This involves using common sense practices to avoid situations that promote disease development. For example, do not use overhead watering late in the day in crops with a dense canopy because this creates conditions favorable for the development of *Botrytis.*

Resistance

This involves the inherent ability of a host plant to remain healthy or resist attack, even though a pathogen is present and/or the environment is conducive to pathogen development. For example, many Rieger begonia cultivars are being bred with resistance or tolerance to powdery mildew.

Protection/prevention

Fungicides can be applied before any disease is observed as a preventive measure to protect crops during periods when conditions are conducive to disease development. However this proactive approach should be taken judiciously and only under specific crop conditions or crop staging. For example, application of a fungicide such as Decree at the end of the poinsettia crop can protect the bracts from *Botrytis* infections. This is often appropriate when outdoor conditions are cool and wet and the temperatures within the greenhouse have been lowered to tone the crop prior to shipping.

Another good example is applying a fungicide to Easter lilies just after visible bud for *Pythium* root rot. It is well documented that during the phase of rapid bud expansion, root rot typically sets in and results in lower leaf yellowing.

Eradication

Plant pathogens can be eliminated via several means, such as steam pasteurization of ground beds or rockwool slabs, to eliminate root-borne diseases and nematodes. Sanitizing products such as chlorine bleach or quaternary ammonium chloride compounds can effectively control bacteria or fungal spores in dust or on surfaces of benches, in or on irrigation lines and emitters, and on tools used for propagation or production.

Plant breeders and primary propagators routinely index and use tissue culture techniques to maintain vegetatively-propagated plants free of plant-infecting bacteria and viruses.

Therapy

Treat infected plants to prevent further sporulation and spread of the fungus. For example, Nova is sprayed on rose foliage to kill the mycelium of the powdery mildew fungus.

Basic Integrated Disease Control Strategies

Symptom recognition

Successful disease management begins prior to the start of each crop. Knowing the diseases most likely to infect the crop is helpful in anticipating the potential problems that may arise. However, with so many new plant introductions each year, the susceptibility of these plants to disease is not known. Experience has shown that most new plant material is susceptible to many of the same diseases that have frustrated growers for decades.

> Becoming familiar with the typical symptoms of the most common economically important diseases is important in quickly recognizing and identifying a disease in its early stages.

Monitoring

Regular crop monitoring and record keeping provides reliable information to guide an IDM program if the crop inspection is routine and structured. It is essential to consider monitoring for the presence of plant diseases, just as it is in reviewing crops for PGR application or for irrigation. It must be considered part of the production process. Concentrating on known susceptible crops or areas within the greenhouse that are typical locations for certain problems (e.g. powdery mildew near door entrances) can save time when growing a range of crops.

To monitor effectively for disease incidence and development, it is important to inspect foliage and flowers (if present) weekly. Roots should also be checked at least bi-weekly, which is practical for potted crops although not for soil-grown cut flowers. Check EC and pH biweekly for each crop grown as these two factors usually predispose plant roots to attack by various root rot pathogens. Detecting diseases early makes control easier and may mean containing a problem with only a spot spray or other localized action.

Monitoring can only be successful when pertinent information is recorded. This is beneficial when attempting to identify a crop problem or when completing a post-crop production review. The following information should be recorded when monitoring or applying a fungicide:

- date
- compartment or section in the greenhouse
- crop species and cultivar
- stage of plant development
- diseases present or suspected
- control action (pesticide used, rate, area treated, time taken, etc.)
- greenhouse environmental conditions (temperature, RH, light levels, shading used)

Environmental Control and Manipulation

Environmental factors such as light, air temperature, plant temperature, RH, air circulation, media composition, pH and EC, as well as the nutritional status of the crop, impact both the health of the plant and the diseases that attack them. The use of environmental controls to manage diseases is complex because of the simultaneous effect on crop production.

Know and understand the conditions required for both the optimal growth of the crop and the common diseases of that crop:

- Avoid extremes or, more importantly, rapid changes in RH. This minimizes the time period and conditions suitable for *Botrytis* or powdery/downy mildew to develop.

- Be aware that temperatures of leaf surfaces are lower in plastic houses than in glass houses, because of greater heat loss due to far-red radiation.

- Avoid poor air circulation within the greenhouse. This can cause uneven temperatures throughout the crop. It can also lead to free moisture forming on the plants, particularly at night, which creates ideal conditions for mildew and *Botrytis* infections.

- Avoid extremes, as much as possible, for the crops. For example, the combination of high temperature and over-fertilization promotes *Fusarium* crown and root rot in cyclamen, while the combination of high temperature and high RH is favourable to *Rhizoctonia* attacking cuttings during or just after propagation. Also avoid low temperatures to prevent outbreaks of *Pythium* in warm-temperature crops.

Modification of Cultural Practices

Chronically stressing plants makes them more susceptible to attack by disease pathogens. Plants are stressed when the root and/or shoot environments are neglected.

Understand the growing requirements of the crops being produced. Not all crops will tolerate the same conditions. For example, Easter lily and primula require very different root management; lily roots cannot tolerate being overly wet and starved for oxygen while primula cannot tolerate having the media drying out.

Monitor the media or substrate pH and EC every week if necessary. Avoid fertilization when soluble salts are high. The definition of high salts varies with the crop and its stage of development (see Chapter 3, *Water, Growing Media and Crop Nutrition*, on page 17). High salts damage root hairs and young roots. These wound sites become entry points for disease pathogens like *Pythium* and *Fusarium*.

Use clean containers and porous, well-draining media to minimize the potential for pathogens such as *Pythium* and *Phytophthora*.

If foliar diseases are an ongoing problem, review temperature, RH, air circulation patterns and watering practices. Often, by maintaining higher night temperatures, higher minimum overhead pipe temperatures or ensuring that air exchange occurs regularly throughout the night, the incidence of foliar diseases can be lessened.

Sanitation and Roguing

Sanitation is the first step in any disease management program. If a source of infection or infestation is constantly present due to poor hygiene, disease management programs will be expensive and frustrating. Proper sanitation practices are the first line of defence in the greenhouse, outdoors in the immediate vicinity of the greenhouse and during every stage of crop production.

Proper greenhouse sanitation is a continual, year-round process. Cleanliness on its own may not totally control pest problems, but it is a basic component of any control program. It is important to:

- Use footbaths between greenhouse compartments, particularly between propagation and stock plant areas. Proper maintenance of these footbaths is essential. Follow the label of the product being used. Household bleach is not recommended for this purpose.
- Remove dead and dying plants, leaves and flowers as detected. In geraniums, removing and disposing of all flowers away from the greenhouse plays a significant role in reducing the incidence of *Botrytis*. Do not leave diseased plants under benches.
- Place rogued plants with difficult to control diseases in commercial garbage containers and dispose of them in a landfill to reduce potential sources of inoculum.
- Dedicate wheelbarrows or soil carts used to discard diseased material strictly for disposal purposes. If this is not possible, disinfect after every use.
- Have employees wear disposable gloves when handling diseased plant material. Otherwise, employees should wash their hands thoroughly with soap or bactericidal hand lotion before performing another function. They should also wash their hands between cultivars when taking cuttings.
- Store normal crop residues well away and downwind from the greenhouse to prevent particles of media or plant tissue being blown or sucked into the greenhouse. It is preferable to cover plant residues; alternatively, move residues off-site on a routine basis.
- Keep walks and the surfaces of benches clean. Sanitize between crops.
- Carefully check both the foliage and roots for disease when bringing new vegetative cuttings into the greenhouse for stock plant production. It is advisable to initially isolate new plant material.
- Avoid over-wintering garden or houseplants in the greenhouse, as they may act as a source of disease.
- Maintain proper drainage to eliminate puddles and wet surfaces, as these provide ideal breeding sites for fungus gnats and shoreflies. These insect pests are a possible source of infection for root diseases such as *Pythium* and *Fusarium*.
- Keep the greenhouse free of weeds that may harbour diseases like impatiens necrotic spot virus/tomato spotted wilt virus (INSV/TSWV) or insects that can be vectors of disease.
- For soil-grown crops, steam soil before planting winter crops to minimize the carryover of root and crown rot pathogens. See *Steam*, on on page 74.
- Steam traditional propagating benches regularly.
- Disinfect propagating benches and trays before propagating and between each round of rooting to eliminate bacteria and fungi.
- Use expanded metal benches rather than wooden benches for easy cleaning and to minimize

the spread and survival of pathogens during propagation.

- Sweep or vacuum bench surfaces before sanitizing to ensure the best possible effectiveness of sanitizer. Peat and other organic matter left on the bench prior to sanitizing reduce the effectiveness of most sanitizing agents. If necessary, wash down benches and walls with horticultural detergents to remove algae before sanitizing.

- Empty and sanitize tanks used to hold recirculated nutrient solution at the same time as concrete floors or troughs to prevent recontamination of the production areas.

- Dip cutting knives in 70% alcohol between cultivars to prevent the spread of disease. Between crops, perform a general disinfection of the greenhouse structure (walls), heating pipes, walks, benches or equipment if possible.

Biosecurity

Biosecurity is a process to protect a geographic area or individual facility from pests and diseases. It includes reducing the risk of the introduction of new pests and diseases and eradicating or effectively managing the spread of those that have already arrived. Taking common sense precautions to prevent pests and diseases from entering the farm is a worthwhile investment. In the context of greenhouse floriculture, this should entail proper sanitation, thorough inspection of incoming cuttings and the other integrated disease strategies described in this chapter and in Chapter 4, *Integrated Insect and Mite Management,* on on page 39. The implementation of a biosecurity protocol for visitors entering the facility also plays an important role in reducing the potential for the introduction and establishment of new pests and diseases.

Disinfectants

These products play an important role in the prevention and control of fungal and viral pathogens within the greenhouse. There are a number of products available including the following:

- *Agribrom* – used to control microbial slimes in greenhouse evaporative cooling systems and to control algae and microbial slimes in irrigation systems. Maintenance of desired levels in automatic irrigation systems has proven difficult for most growers even when using a brominator.

- A 0.5–1% final solution of sodium hypochlorite bleach – mix 1 part common household bleach with 10 parts water to obtain a final solution of 0.5%. For a 1% solution, mix 1 part bleach to 5 parts water. Use a higher strength solution (up to 1%) in cases of serious disease outbreaks or when disinfecting wooden benches. Chlorine is very effective but rapidly volatilizes when mixed in water, with the strength reduced by 50% in two hours. Chlorine fumes can be harmful to plants, so if plants are present in adjacent areas, ensure adequate ventilation. Organic matter very quickly inactivates the chlorine. Be aware that residual chlorine can be released from surfaces when rewetted if rapid drying has occurred.

- *Horti-Klor* – a chlorinated cleaner or detergent that can be used initially to remove algae and plant residue from packing equipment. Follow manufacturer's directions.

- *Chemprocide* – a quaternary ammonium chloride compound with broad fungicidal and bactericidal activity, recommended for general surface disinfection and foot baths.

- *Floralife D.C.D.* – a quaternary ammonium chloride compound with fungicidal and bactericidal activity. Surfaces should be pre-cleaned prior to disinfection and should remain wet for 10 minutes.

- *Virkon* – potassium monopersulphate, a disinfectant with broad fungicidal, bactericidal and virucidal activity.

- Quaternary ammonium chloride compounds are quite stable because the chlorine is not volatile, but they disinfect in a way similar to chlorine bleach. As with bleach, contact with any type of organic matter will inactivate the disinfectant. Therefore, it is very important to remove as much organic matter as possible prior to application.

Soil pasteurization methods

Greenhouse media containing field soil and cut flower soil-based ground beds typically contain weed seeds, insects, bacteria and fungi that may be harmful to the plants being grown. This includes potting mixes and their components, unless guaranteed sterile or pasteurized by the manufacturer. Pasteurization of media containing soil is important to eliminate these harmful organisms. Ideally, this is accomplished without injuring beneficial soil organisms.

Few growers continue to use soil as an amendment to their growing media because of the difficulty in sourcing quality top soil, concerns with regard to herbicide residues, the cost of steaming and the associated labour costs.

Soilless media, although not sterile, is essentially disease-free because of the low pH of the sphagnum peat being harvested from the peat bogs.

Steam

Steam is the most common heat source for pasteurization. There are different ways of handling steam, depending on the type of crop being grown. When pasteurizing soil in bulk for vegetable seedlings or potted plants, some growers find it efficient to inject steam into the bottom of a modified soil wagon or similar enclosed vehicle. After cooling, move the pasteurized soil to the area in which it will be used, or store covered in an isolated area where the possibility of contamination is minimized.

Growers of cut flower or vegetable crops should follow one of two techniques when steaming soil in ground beds:

- Ground beds are initially rototilled and then covered with a tarpaulin. Steam is injected directly under the tarpaulin through either a canvas hose or a perforated, flexible plastic field tile to ensure even distribution. Soil should be of fine tilth and moist to allow rapid, uniform penetration of the steam. Many growers use a small fan to assist in raising the tarpaulin more quickly. A soil thermometer should be inserted into the soil to at least 15 cm depth to monitor temperature. Check Table 7-1. *Time-Temperature Relationships to Destroy Undesirable Organisms,* on this page. It shows that most organisms of concern to growers can be eliminated under ideal conditions of 60°C for 30 minutes.
- If rototilling after steaming, it is important that the rototiller is sanitized and that the soil is not tilled more deeply than the depth of treated soil.

If reusing rockwool, note that steaming time depends on the wetness of the rockwool and the steam temperature. Steaming at 90°C for 30 minutes should be adequate. Generally, the wetter the rockwool, the longer the steaming period required. For this reason, the substrate should be as dry as possible before steaming. Rockwool stacked on pallets without polyethylene bags can be steam-sterilized in two hours. Rockwool wrapped in polyethylene requires five hours of steaming. Rockwool should not be stacked higher than 1.5 m. To stabilize the stacked slabs, place each row at a right angle to the previous row. In addition, leave a 2.5 cm space between individual slabs to allow for better steam penetration.

If reusing compost material containing used potting media and discarded plants, thorough steaming should be completed to minimize the disease potential.

Table 7-1. Time-Temperature Relationships to Destroy Undesirable Organisms

Weeds (most)	70–80°C for 15 min.
Bacteria (most)	60°C for 10 min.
Fusarium	57°C for 30 min.
Botrytis	55°C for 15 min.
Nematodes	55°C for 30 min.
Rhizoctonia	52°C for 30 min.
Sclerotinia	50°C for 5 min.
Pythium	46°C for 40 min.

When soil temperatures rise above 82°C, beneficial soil organisms begin to be destroyed. If the soil is heated to a temperature that is too high for too long, it becomes sterile. It is then subject to a greater degree of infection than previously, as all beneficial organisms have been destroyed. There are many other undesirable effects of over-steaming, such as:

- excessive ammonia release
- manganese toxicity
- higher total salt levels
- destruction of organic matter

Aerated steam

Aerated steam is being used more widely than it used to be. In this system, steam mixes with air in a chamber. The mixture is used at 70°C to pasteurize soil while avoiding any of the hazards of over-steaming. Unless there are specific problems, a soil temperature of 70°C is adequate for most insect and disease problems.

Electric soil pasteurizers

Electric soil pasteurizers are useful when pasteurizing small volumes of soil or when no other method is available. Note that these can overcook the soil very easily. For the soil temperature between the finned heat sources to reach 82°C, the fins themselves must be at a higher temperature. Media must be moist to better conduct the heat.

Chemical fumigants

Chemical fumigants such as Basamid and Vapam can be used to pasteurize soil for potting or in greenhouse beds or benches, but are rarely used today. Each of these fumigants has a specific rate and activity against soilborne insects, diseases, nematodes and weeds. Note that some formulations may be less effective against certain types of pests — always read the manufacturer's label. Use only when greenhouses are free of crop to avoid damage from accidental exposure to escaped fumes. The fumigant Telone II B is only registered for treatment of soils for outdoor flower production.

Fumigants listed in Table 7-2. *Chemical Fumigants for Soil Treatments,* on this page, are effective as preplanting treatments for greenhouse soil beds. The amounts shown are for use on 100 m^2.

Table 7–2. Chemical Fumigants for Soil Treatments

Control of Nematodes Only	
Product	**Rate (per 100 m^2)**
Telone IIB*	2.0 L
Telone C-17*	2.0 L
Control of Nematodes, Fungi, Insects and Some Bacteria	
Basamid (granular)	3.25–5 kg worked into a depth of 15–23 cm
Vapam (liquid)	10 L

* Telone IIB and Telone C-17 are registered for use on outdoor floral crops only. They will be withdrawn from the market and cannot be used after December 31, 2011.

Weed Control

Weeds can act as a reservoir for diseases and their control is an important part of any disease management program. For more information on weed control see *Weed Control Methods,* on on page 42.

Pathogen-Free Plant Material

Purchase cuttings from specialized propagators or from plant breeders to minimize the chance of introducing diseases into a greenhouse operation. If possible, isolate new plant material to reduce the potential for contamination.

Change stock plants regularly. This may mean quarterly or every six months, depending on the crop. Do not carry stock of any bedding plants from one season to the next.

Do not bring clean stock into the same production zone until the old has been moved out and the area is thoroughly sanitized. Alternatively, isolate the clean stock in a separate area.

Vector Control

Insects spread many viruses and viroids. For example, aphids spread Aster yellows in chrysanthemum, while INSV/TSWV is transmitted by western flower thrips. Consider using screening on open cooling vents to block many insect pests from the greenhouse. This makes control of the insect population easier.

Fungus gnats can spread the spores of *Pythium.* The larvae damage young roots through feeding activity. Research has shown that *Pythium* oospores (thick-walled sexual spores) are routinely transmitted through the gut of fungus gnat larvae. In addition, the adult can transfer the pathogen with its legs and mouthparts. Controlling algae growth through judicious watering practices and providing adequate drainage under benches helps control fungus gnat and shorefly populations and minimizes the spread of disease pathogens.

Host Plant Resistance

Many plant species display varietal differences in their susceptibility to disease attack. Breeding of crops can provide growers with cultivars resistant to one or more insects or diseases. For example, greenhouse tomato growers seldom experience problems with *Fusarium* crown and root rot because resistant varieties have been developed. Greenhouse growers are increasingly using powdery mildew–tolerant cucumber varieties. Although ornamental plant breeders have not taken great advantage of host plant resistance, it offers potential for future advancements in pest management.

In the meantime, growers with pest problems can improve their pest management program by looking closely at the varieties grown and how these varieties are affected by pests. Use susceptible varieties as indicators for pests and diseases. Spot-spray the susceptible variety when pests or diseases occur to provide effective control and reduce the amount of pesticide applied. Although market demands determine the varieties grown, it may be possible to eliminate or reduce the amount of a susceptible variety and replace it with a more resistant one.

Some cultivars of crops are less susceptible to certain diseases than others. Plant breeders are beginning to use plant breeding to introduce disease resistance into crops.

Chemical Control

Fungicides have been the conventional approach to disease control. The role of fungicides can vary from protecting healthy plants to treating infected plants and eradicating diseases. It is necessary to rotate fungicides with different modes of action to reduce the likelihood of resistance development. Rotation of fungicides has become increasingly important as most newer fungicides have a single-site mode of action and are more prone to resistance development. Reducing the use of and reliance on fungicides is also critical in resistance management. An important aspect of reducing fungicide use is developing a better understanding and appreciation of the role of cultural practices in disease management.

Biological Control of Diseases

Biological disease control involves the use of naturally occurring fungi and bacteria that strongly suppress disease-causing organisms without harming the crop. Mechanisms of action include competition, antibiosis, parasitism or induced resistance. Most biocontrol products should be considered preventative or suppressive and their use should start with the planting of a crop. Note that labels indicate suppression of disease, not control of disease.

Microbial fungicides having received Canadian registrations for use on greenhouse grown ornamental crops are listed below. For root diseases:

- Mycostop is registered for the suppression of damping-off caused by *Pythium,* root and crown rot caused by *Phytophthora,* and wilt caused by *Fusarium* on greenhouse ornamentals. The soil bacterium *Streptomyces griseoviridis* K61 is the active ingredient. Its mode of action includes hyperparasitism (microbe deprives pathogen fungi of nourishment by colonizing plant roots in advance of the fungi) and antibiotic production, which inhibits pathogen growth. Because the effect is preventive, drench Mycostop immediately after potting and repeat the treatment every 3–6 weeks, depending on disease pressure.

- Rootshield is registered for suppression of *Fusarium, Pythium* and *Rhizoctonia* on all ornamental crops. The naturally occurring fungus *Trichoderma harzianum KRL-AG2* strain provides protection by colonizing the surface of the roots and root rhizosphere through the utilization of waste products produced during normal root growth. It also parasitizes disease-causing fungi through the release of enzymes that cause breakdown of their cell walls. It is recommended this bio-fungicide be applied soon after germination, rooting or sticking of vegetative cuttings. Two formulations are available: a granular formulation that can be incorporated into the growing media, or a drench to be applied to newly transplanted seedlings or cuttings and to apply at regular intervals.

- PreStop is registered for suppression of *Pythium, Rhizoctonia* and *Phytophthora* on a variety of ornamental and bedding plants. It is also registered against *Botrytis* on various ornamentals. The active ingredient is the fungus *Gliocladium catenulatum* strain J1446, which works by competing with plant pathogens for colonization of plant root surfaces, depriving the pathogen of nutrients. Additionally, it produces enzymes that break down the cell walls of pathogens, an action known as hyperparasitism. It can be applied as a growing medium treatment or soil drench for root diseases, or as a foliar spray for *Botrytis*.

- *Bacillus subtilis* MBI 600 is registered for incorporation into soilless media manufactured by Premier. It is registered for the suppression of damping off and root rot caused by *Pythium* spp.

- Contans is registered for the control of sclerotia activity of Sclerotinia in soil grown greenhouse cut flowers and for suppression in outdoor grown cut flowers. The active ingredient, fungal strain *Coniothyrium minitans* Strain Con/m/91-08 should be applied to the soil three months prior to anticipated Sclerotinia outbreak in a susceptible flower crop.

For foliar diseases:

- Rhapsody contains the bacterium *Bacillus subtilis* strain QST 713 and is registered for suppression of powdery mildew, *Botrytis* and leaf spots on a number of greenhouse and outdoor ornamental crops. *Bacillus subtilis* produces chemicals that break down the cell membrane of disease organisms. It also inhibits pathogens from colonizing the plant. There is a range of rates depending on the disease pressure and it should be applied at 7-day intervals.

- Actinovate SP is registered for suppression of powdery mildew on greenhouse and field-grown gerbera daisy and peppers and for suppression of *Botrytis* and powdery mildew on greenhouse and field-grown strawberries. The active ingredient is the bacterium *Streptomyces lydicus* strain WYEC 108, which colonizes the leaf surface and competes against foliar pathogens. It is also believed to produce antibiotics that act against plant pathogens. For powdery mildew in gerbera, it should be applied as a foliar spray at transplant with 2 subsequent sprays at 7-day intervals.

- PreStop is also registered as a foliar spray for *Botrytis*. For mode of action, see description on the first PreStop bullet under *Biological Control of Diseases*, on page 76.

As with pesticides, biocontrols are not a panacea for disease control. Biocontrol agents will not replace proper crop management strategies.

Achieving Successful Disease Management

Successful disease management can be achieved if these measures are followed:

- Emphasize prevention rather than cure. This is critical in any production system, but is especially true when crops are being grown in closed sub-irrigation systems.

- Monitor crops weekly or (at least) biweekly.

- Walking the crop(s) is essential to early detection. This involves checking the crop foliage and root systems and both manual and computer-controlled environment conditions.

- As a grower/manager, keep detailed records that enable merging of cultural, environmental, and insect and disease data for analysis.

- Monitor the weather to help anticipate potential disease problems. For example, a cool, cloudy and wet summer with the central heating system off creates ideal conditions for downy mildew development. Poinsettia propagators can anticipate slow, uneven rooting and increased *Botrytis* rot without supplementary heating.

- The employee responsible for monitoring must work closely with the person responsible for overall crop scheduling. Ideally, the individual in charge of growing should be the one who monitors for disease and environmental control. In many operations, this should be done by an employee dedicated to the task because the owner/grower often has other issues on which to focus.

- Correct diagnosis is crucial. Without correctly identifying the pathogen, control using cultural or chemical strategies is impossible. Soil-borne fungi are the most difficult pathogens for growers to identify. Send samples to the Pest Diagnostic Clinic, University of Guelph, for accurate diagnosis. See Appendix E. *Diagnostic Service*, on page 132, for further details. For some diseases, ELISA disease diagnostic kits for grower use are available from companies such as Agdia.

- Develop a thorough understanding of the diseases that affect the crops being grown. Correct use and timing of management strategies then becomes part of an ongoing process.
- Because disease pathogens are microscopic, learn to anticipate when possible pathogen infection periods are likely to occur. By the time the problem is visible, the pathogen has usually been present for some time and is more difficult to control.

8. Major Greenhouse Diseases

Quarantine Pest Problems

This chapter describes the most common disease problems in greenhouse ornamental production. However, it is important to realize that some of the most destructive diseases are very infrequently found but when they are, the impact can be devastating. A quarantine pest is "a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (FAO, 2004). Some of these pests or diseases are known to be a potential risk and are regulated by the Canadian Food Inspection Agency (CFIA). Other pests may have no known potential for damage until they occur, at which time the CFIA will decide on the risk they present. If found, regulated pests must be reported to the CFIA who will then decide what action must be taken to address the pest problem. Although this action can have serious financial impacts on individual growers, it is important to the industry that growers report suspected problems. Failure to do so could threaten the export of ornamental plants to countries such as the United States. Known quarantine diseases as of June 2010 are noted within this chapter and include chrysanthemum white rust, Ralstonia bacterial wilt of geranium and Ramorum blight and dieback (sudden oak death). For more information and the most up-to-date listing of regulated pests and diseases, visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA office (see Appendix D. *Other Contacts,* on page 131).

Fungus Diseases

Botrytis (grey mould)

The fungus known as *Botrytis cinerea* causes many common diseases of greenhouse ornamental and vegetable crops. "Grey mould" is often used to describe the disease because of the prolific sporulation of grey or brown spores, a characteristic symptom that occurs on infected tissues under appropriate conditions.

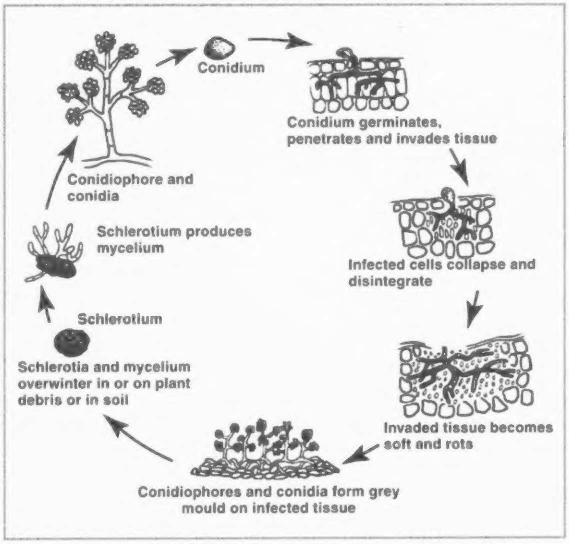
Botrytis disease symptoms appear as flower spotting and blight, leaf blights, bud and cutting rot, stem cankers, and corm or bulb rots.

Infections occur when germinating conidia (spores) penetrate healthy succulent leaf or flower tissue, stomata, or wounds, or when pieces of fungal mycelium or infected plant tissue come in contact with healthy host tissue. See Figure 8-1. *Botrytis Life Cycle,* on this page.

Botrytis readily attacks healthy or senescing, soft, nutrient-rich flower or bract tissues of most flowers including cyclamen, geranium, rose and poinsettia. Mycelial infections typically occur when infected flowers or leaves fall onto healthy tissues below and stick to wet leaf surfaces.

Latent infections occur as described above but show no visible symptoms because of unfavorable environmental conditions. When environmental conditions change, symptoms may appear. This typically occurs with cut flowers, which appear healthy when cut and packed but have tan-brown spots on the petals when unpacked at the retail destination.

Figure 8-1. *Botrytis* Life Cycle


Conidium
Conidium germinates, penetrates and invades tissue
Infected cells collapse and disintegrate
Invaded tissue becomes soft and rots
Conidiophores and conidia form grey mould on infected tissue
Schlerotia and mycelium overwinter in or on plant debris or in soil
Schlerotium
Schlerotium produces mycelium
Conidiophore and conidia

Botrytis is ubiquitous — the spores are always present. The conidia disperse very readily in air currents and in or on water droplets. Fluctuating relative humidity levels trigger the release of spores. Spore germination can occur in less than three hours, with sporulation occurring within eight hours of initial infection.

Botrytis infections usually occur during cool, wet or humid weather conditions, which favour infection and sporulation. Free moisture containing dissolved nutrients acts with temperature to determine the initial infection and subsequent lesion development. Optimal conditions for *Botrytis* growth are temperatures between 15–23°C and relative humidity (RH) greater than 90% or microscopic free moisture on plant tissue, which forms as a result of cooler plant tissue temperature compared with the surrounding air temperature.

Disease control

Botrytis is often considered a "disease of bad management." Use appropriate crop management techniques and manipulation of the greenhouse environment to minimize its impact. For example, reduce the relative humidity at night by maintaining warmer night temperatures and proper ventilation practices.

Use computer-controlled humidity monitoring programs. Avoid formation of free moisture, which occurs at night whenever the leaf or plant temperature is lower than the air temperature or the air cools below the dew point. This happens frequently in the evening with a clear sky or early in the morning when the air heats up more quickly than the plant surface. Use minimum pipe temperatures in summer when nights are warm and humid.

Calibrate RH sensors regularly. Keep RH below 85%. Do not allow leaves to stay wet more than 3–4 hours.

Air circulation is critical for maintaining dry plant surfaces and usually depends on proper plant spacing. Remove excessive foliage in crop canopy if necessary.

Sanitation before and during crop production is essential. Remove senescing flowers and leaves.

Avoid overhead watering wherever possible. When using overhead irrigation, water early during the day to allow foliage and canopy to dry before evening.

Fungal leaf spots, flower spots and blights

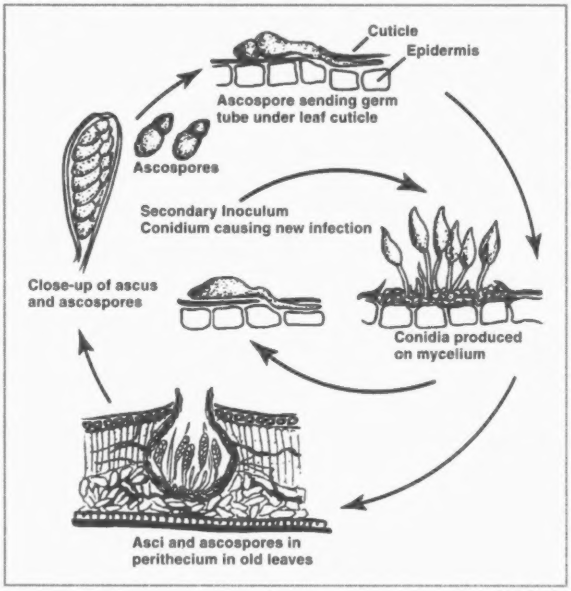
Fungi cause all of these diseases, with symptoms varying greatly. See Figure 8-2. *Leaf Spot Disease Life Cycle,* on this page.

The more common fungi-causing leaf spots include *Alternaria, Ascochyta, Cercospora, Phyllosticta, Gloeosporium,* and *Septoria.* Most produce abundant conidia. Spores of these fungi are wind-borne and can be splashed around when watering.

Blights or spots can appear on leaves, stems or flowers depending on the organism present. Many attack all three of the plant parts, but none attack the roots or crown. Leaf blights and spots usually appear on the lower foliage and work their way up through the plant canopy. Many of the pathogens produce characteristic spots or lesions, such as "bull's-eye" spots with a reddish border or tan-coloured spots with concentric rings. Spots may be circular, angular or irregular.

Leaves must be wet for infection to occur.

Figure 8–2. Leaf Spot Disease Life Cycle


Cuticle
Epidermis
Ascospore sending germ tube under leaf cuticle
Ascospores
Secondary Inoculum Conidium causing new infection
Close-up of ascus and ascospores
Conidia produced on mycelium
Asci and ascospores in perithecium in old leaves

Disease Control

To control disease:

- Keep foliage and flowers as dry as possible.
- Avoid overhead watering.
- Provide good air circulation.
- Remove infected plant material from the greenhouse.

- Use disease-free propagating material.
- Most broad spectrum fungicides will provide effective control. Check the label for registered uses.

Powdery mildews

These common fungal diseases cause an easily recognized white powdery growth on leaves, stems, petioles and floral parts of infected plants, quickly making plants unmarketable. Several genera are involved, including *Erysiphe, Leveillula, Microsphaera* and *Sphaerotheca*. It is important to note that the fungus that causes powdery mildew on one plant species generally does not affect another. Because powdery mildews are obligate parasites, they require living plants for completion of their life cycle. Each of these fungi forms a network of hyphae over the leaf or stem surface, from which it penetrates epidermal cells to derive its nutrients via nutrient pegs known as haustoria.

Growth may begin as small, discrete spots but can spread to cover the entire upper surface of the leaves. On many plants, the fungal growth becomes felt-like. This happens when ideal conditions produce abundant superficial mycelia bearing many colourless conidia (spores). In some plants, the leaves develop a reddish discolouration where the infection occurred. Severe infections will cause leaf stunting, yellowing and curling.

In the greenhouse, powdery mildew fungi have a simple life cycle. Single-celled conidia form in a long chain on short, erect fungal stalks. See Figure 8-3. *Powdery Mildew Life Cycle,* on this page. This creates the "fluffiness" usually associated with powdery mildew. Under favorable environmental conditions, conidia chains are produced and released at a usual rate of one conidium per day or diurnal cycle. Conidia mature and are ready for release in 24 hours. A drop in relative humidity and the heating and drying effect of solar radiation promote spore release.

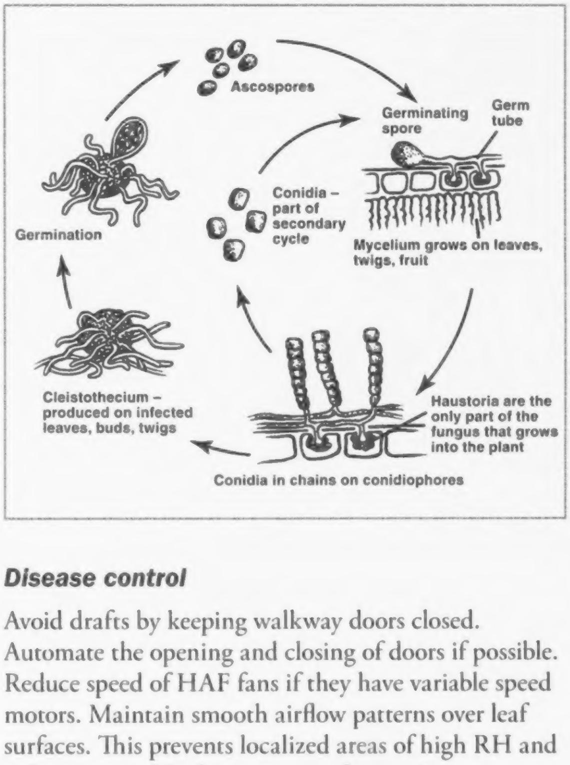
Conidia need a RH of 95% or a near-zero vapour pressure deficit for more than 3-4 hours to germinate and penetrate the host's leaf or stem epidermal cells. The mycelium produces haustoria or nutrient pegs, which provide a constant nutrient supply for fungal growth and conidial stalks as it grows over the leaf surface. Within 48 hours of inoculation, mature conidia can release to infect other leaves or plants.

Relative humidity, temperature, light, leaf wetness and air movement (e.g. drafts) all influence the severity and spread of powdery mildew infections. Because of these interrelated environmental factors, use an integrated approach.

Excessive and turbulent air movements, such as drafts near open doors, improper spacing of HAF (horizontal air flow) fans, or improper fan sizing or speed, promote infection and spread.

Leaf wetness episodes promote fungal development. The occurrence and persistence of leaf wetness are affected by leaf-to-air temperature gradients, the degree of leaf radiant energy loss, solar radiation and leaf transpiration.

Figure 8–3. Powdery Mildew Life Cycle


Ascospores
Germinating spore
Germ tube
Conidia – part of secondary cycle
Mycelium grows on leaves, twigs, fruit
Germination
Cleistothecium – produced on infected leaves, buds, twigs
Haustoria are the only part of the fungus that grows into the plant
Conidia in chains on conidiophores

Disease control

Avoid drafts by keeping walkway doors closed. Automate the opening and closing of doors if possible. Reduce speed of HAF fans if they have variable speed motors. Maintain smooth airflow patterns over leaf surfaces. This prevents localized areas of high RH and reduces air and leaf temperature fluctuations.

Using computer technology, establish reasonable environmental parameters to maintain the desired RH levels through ventilation and heating. Avoid sudden changes in either temperature or RH due to venting. High RH on its own does not necessarily promote powdery mildew.

Rely on the radiant heat from both the crop-zone and above crop heating lines to maintain a drier, warmer crop environment. Establish a higher minimum pipe temperature if using hot water, or apply short pulses of steam into the above crop heating lines to create a source of radiant heat.

During the evening in late summer, the dewpoint is often reached in the greenhouse as temperatures drop. Closing shading or energy curtains and/or using high-pressure sodium lighting during the winter months will help prevent radiant energy loss from leaf surfaces by keeping them warmer.

Downy mildews

Peronospora, Plasmopara and *Bremia* are the three downy mildew genera that commonly attack ornamental plants. The downy mildews have become more common and are difficult diseases to control. These fungi are primarily foliage blights but will attack and spread rapidly into young, green tissues of growing tips and flower buds causing stunting and distortion. Some of the most commonly attacked crops include rose, snapdragon, impatiens, lisianthus, sunflower, coleus, cineraria, Argyranthemum, pansy, basil and numerous perennials.

For most crops, masses of tan, white or purple fuzz (spores) can be found on the undersurface of the leaves. Leaves of most plants will tend to cup along the margin and curl downward. Upper leaf surfaces show chlorosis (yellowing) where the infection is located.

The development and spread of downy mildews depend on the presence of water films on the plant tissues and on high RH during cool periods (but not during hot periods).

Rose leaves develop purplish-red spots on upper leaf surfaces. They become distorted, have symptoms typical of pesticide phytotoxicity, turn yellow and abscise in great numbers. Rose downy mildew produces very few visible spores unless optimal conditions exist.

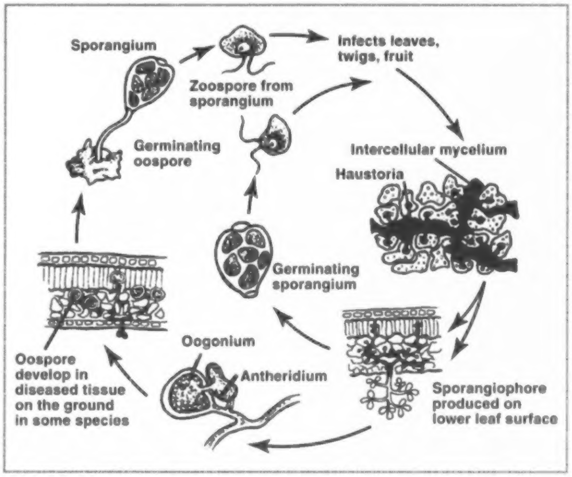
Downy mildew of snapdragons produces masses of grey-brown spores that resemble thick velvet. Foliage becomes distorted and if infection occurs in the seedling stage, it quickly becomes systemic and infects the growing tip or developing flower spike. Losses can be severe.

On impatiens, yellow stippling similar to spider mite injury is commonly observed, along with leaf yellowing and masses of white spores. Symptoms on sunflower are very similar.

Downy mildew fungi can survive on infected plant debris in the soil or on weed hosts.

Sexual reproduction results in oospore production, which carries the fungus through periods unfavorable for vegetative growth. See Figure 8-4. *Downy Mildew Life Cycle.*

Figure 8–4. Downy Mildew Life Cycle


Sporangium
Infects leaves, twigs, fruit
Zoospore from sporangium
Germinating oospore
Intercellular mycelium
Haustoria
Germinating sporangium
Oogonium
Antheridium
Oospore develop in diseased tissue on the ground in some species
Sporangiophore produced on lower leaf surface

Disease control

Manipulating the environment combined with fungicide applications can prevent further spread to non-infected plants. Fungicides will not cure systemic plant infections.

Control humidity and temperature fluctuations to prevent moisture condensation on the plants. This is often difficult when growing cool season crops, however increasing night temperatures using crop heating and raising minimum night temperatures to reduce the radiant energy loss from leaf surfaces can be effective.

Avoid wetting the foliage when irrigating. Spores are spread by splashing water and air currents. Watering early in the day when possible, will provide time for drying of the plant canopy.

Clean up all crop debris and infected plants and remove from the greenhouse, as the organism survives between crops on plant debris.

Many epidemics begin during extended periods of cool, damp weather, when growers attempt to economize on fuel consumption by adopting low temperature set points or by not operating the heating system during the late spring or early fall.

Fungal wilts

Wilt diseases cause a whole plant, a portion of a plant or a major branch to wilt. Other symptoms include vascular discolouration, stunting, and varying degrees of leaf yellowing. Infectious wilts divide into two broad categories:

- Fungal, caused by *Fusarium solani, Fusarium oxysporum* and *Verticillium albo-atrum*.

- Bacterial, caused by *Erwinia chrysanthemumi, Erwinia carotovora, Xanthomonas campestris* and *Ralstonia solanacearum*. For further discussion on bacterial wilts, see *Bacterial Diseases,* on page 90.

Most fungal wilt pathogens are soil-borne, attacking through roots or the crown area. Root hairs and root tips exude nutrient-rich compounds like proteins and enzymes into the media. These stimulate fungal germination and are the first nutrient source for potential pathogens until they are established within the plant host. Bacterial pathogens also need a wound or natural opening including stomata or hydathodes of leaves for invasion.

Fungal wilt pathogen growth is limited to the vascular tissue, while bacterial pathogens spread rapidly into adjacent tissues through maceration (breakdown) of all cell tissue. Both groups of pathogens can be carried in the stems of symptomless cuttings.

Symptoms of *Fusarium* and *Verticillium* are almost identical in some plants and can only be accurately identified through laboratory examination. These pathogens plug the xylem vessels, interfering with the translocation of water and nutrients. Symptoms include wilting, marginal necrosis and yellowing (eventually browning) of older leaves. Plants are usually stunted, bloom production is reduced and the vascular tissue often has a brownish or reddish-brown discolouration. Plants usually die, particularly from an early infection. Many weeks can pass between the initial infection and the appearance of symptoms.

Fusarium can cause stem and crown rots that result in wilting and collapse. The dark-brown to black lesions develop on the stem at, or just below, the soil line, with the leading edge often pinkish or reddish. Infection occurs inward – there is usually no external stem discolouration.

Fusarium is a very common pathogen of a wide range of greenhouse crops. *Verticillium* is much less common, and usually attacks only chrysanthemum, aster and dahlia.

The fungal pathogens persist for long periods as thick-walled resting spores in soil or plant debris. The spores form when plant tissue begins to dry up. Host plant stress makes plants susceptible to a fungal wilt pathogen attack and strongly influences attack severity. Stress for a particular crop can include high or low air or media temperatures, improper watering, fertilization, media pH or EC.

Pathogen spread during propagation is very common. Fungal pathogens are readily spread by water movement through media, splashing, and the physical movement of infected media and plant material within and between greenhouse operations.

Fungus gnat larvae readily spread *Fusarium* spp. spores.

Disease control

To minimize the development and spread of wilt pathogens, maintain good horticultural practices:

- Use pathogen-free cuttings and seeds.
- Remove and destroy all infected plants.
- Sanitize benches and used trays. Do not reuse pots.
- Thoroughly pasteurize beds for soil-grown crops.
- Maintain appropriate temperature and growing media moisture levels for each crop.

Damping-off of seedlings

Rhizoctonia solani, Pythium spp. and *Phytophthora* spp. are the primary causes of this seedling disease complex, which describes a condition affecting germinating seeds and young seedlings. See Figure 8-5. *Disease Cycle of Damping-off and Seed Decay,* on page 84. However *Fusarium, Botrytis* and *Sclerotinia* are also occasionally responsible.

Pre-emergence damping-off

Pre-emergence damping-off kills the emerging radicle (developing root) and hypocotyl during germination or soon after emerging from the seed coat. The young plants never emerge from the media. Growers often mistakenly blame this loss on poor quality seed.

Post-emergence damping-off

Most growers are familiar with post-emergence damping-off. Typically, the stem is invaded at or near the soil surface. The seedling wilts or stunts, the stem collapses and the plant topples over. Stem lesions may appear somewhat water soaked. Other variations of post-emergence damping-off include top rot or top damping-off and root rot.

Wire-stem damping-off

Wire-stem damping-off is usually associated with older seedlings that have been hardened off. Stems are partially girdled with dry, black lesions and a wire-like appearance. Infected plants are stunted and eventually die. *Rhizoctonia solani* is associated with this condition. High media moisture and poor air circulation increase the likelihood of attack.

Rhizoctonia often spreads in a circular pattern in a seedling tray, with fine grey-brown strands of mycelium visible on the surface of the growing media or as an aerial blight infecting the above-ground plant parts.

Water moulds like *Pythium* and *Phytophthora* can attack seeds but commonly induce rot from the tips of the young roots. This is most severe at high moisture levels and cool temperatures.

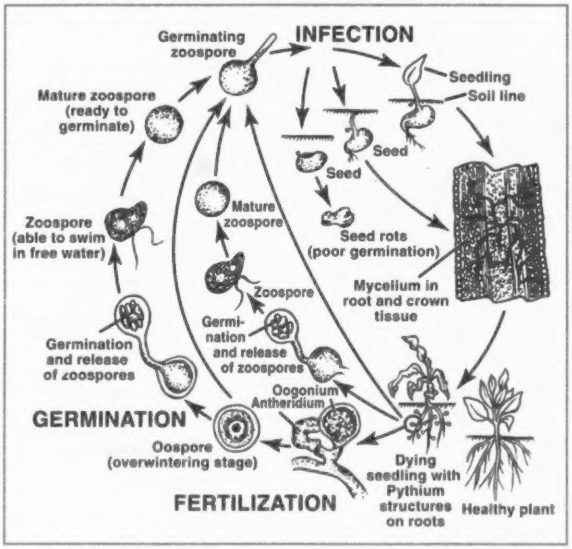
Wet media, poor sanitation, poor ventilation, high humidity, cool temperature, thick stands of seedlings or overgrown seedlings provide ideal conditions for damping-off fungi.

Disease control

To control disease:

- Sanitation is important. These pathogens can spread due to dirty seedling trays, infested media and dirty tools. Remove all infected seedling trays.
- Avoid splashing water, which will spread the pathogens.
- Only use new flats or plug trays for disease-susceptible crops.
- Use a porous, well-drained seedling mix.
- Maintain proper temperatures throughout the various phases of seedling germination and growing on.
- Provide good air circulation.
- Do not contaminate media used for seeding with dust or used media.
- Reduce misting as soon as possible after seedling emergence.

Figure 8–5. Disease Cycle of Damping-off and Seed Decay


INFECTION
Germinating zoospore
Seedling
Soil line
Mature zoospore (ready to germinate)
Seed
Seed
Mature zoospore
Zoospore (able to swim in free water)
Seed rots (poor germination)
Mycelium in root and crown tissue
Zoospore
Germination and release of zoospores
Germi-nation and release of zoospores
Oogonium
Antheridium
GERMINATION
Oospore (overwintering stage)
FERTILIZATION
Dying seedling with Pythium structures on roots
Healthy plant

Crown and root rots

The fungi that most commonly cause crown and root rots are, in order of importance, *Pythium, Rhizoctonia, Phytophthora, Fusarium, Thielaviopsis* and *Sclerotinia.*

Crown and root rot fungi are soil-inhabiting pathogens that constantly threaten commercial greenhouse crops. Note that each of these disease-causing fungi has unique environmental needs.

"Root rot" is a general term for the killing and then rotting of roots by various fungi. Root rot begins when the cortical roots become dysfunctional. They appear water-soaked and have a brown to black discolouration. New root development is reduced. As the rot progresses, the leaves become yellow and stunted; eventually they wilt.

Root rots debilitate individual plants and groups of plants. They compromise crop uniformity and often cause symptoms of nutritional imbalance. This is a serious issue with crops being grown in closed subirrigation systems.

Root pathogens are more difficult to diagnose visually than most foliar diseases.

Disease control

All fungal root rot pathogens can survive in growing media or on infected tissues as mycelium or spores. Most soilless media are considered pathogen-free, and as such have few naturally occurring fungi or bacteria to act as suppressive agents. They can also exist in soil and growing media as oospores, chlamydospores or sclerotia (resting structures with thick cell walls), which remain viable for long time periods. When they contact roots of a susceptible host, they become active (germinate) and begin infecting root tissues. Completely eliminating the inoculum source is difficult, so preventing their activity is the key to control.

All root rot fungi can be spread in irrigation water and by splashing water. Fungi can also be carried over in contaminated media, soil under benches, infected plant residues, reused growing containers, dust, used capillary mats and recirculated irrigation water. Irrigation water from storage ponds collected from runoff may contain root rot pathogens. For disease susceptible crops being grown in a closed system, treatment of recirculation solution is recommended with UV or ozonation being just two options.

Healthy plants resist root rot infection. Crop stress is an important contributing factor to crown and root rots, predisposing plants to attack. Factors contributing to crop stress include fertility level, high EC and media pH, watering practices, air and media temperature, light level, and pesticide and growth-retardant drench applications. Each root pathogen has a different optimum temperature, pH and moisture requirement.

Using growing media drenches effectively

Soil drenches are typically used for the control of root or crown attacking disease pathogens and involve the application of the pesticide to the root zone. The amount of pesticide added varies depending on the pot size and volume of the growing medium, but to thoroughly wet the growing medium in a 15 cm pot requires approximately 150–180 mL. For soil beds, apply 12 L of drench/m^2. Be aware that not all pesticides require the medium be completely wet, so follow the label directions carefully. Treatment of young plants preventatively just prior to transplanting to a larger container is a way of reducing the amount of pesticide used.

Application of soil drenches for crops being subirrigated is a challenge because the roots are all concentrated at the bottom of the pot, while the fungicide is being applied from the top. Also, by applying from the top, the accumulated salts in the top zone of the media are pushed down into the active root zone area, potentially compounding the problem. Discuss available options with a Greenhouse Floriculture Specialist or IPM Specialist.

Growing media should be moist when fungicides are applied to avoid further damage to the root systems of the crop.

For disease control, drenches should not replace a thorough greenhouse pasteurization program, but they are useful for preventing recontamination or eliminating pathogens in the soil or the basal parts of the plant.

Some fungicides are taken up from the soil by plant roots and distributed throughout the plant. This is described as systemic action, and the whole plant is effectively treated against the disease being targeted. Aliette is the only fungicide effective against a root and crown pathogen that is more successful when applied to the foliage and translocated downward in the phloem.

Pythium spp.

Pythium root rot is the most common root rot found in greenhouse production. Several different species including *P. ultimum* (the most common), *P. aphanidermatum* and *P. irregulare* attack many crops.

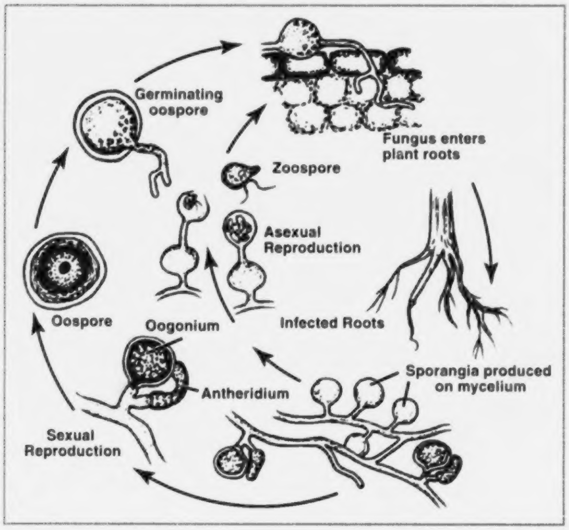
Symptoms vary with the age and development stage of the affected plant. Older-plant infections are usually limited to roots and root hairs. Infected roots are soft, mushy and various shades of brown. The rot begins as water-soaked brown rot of the root tips and cortex. Usually the cortex sloughs off, leaving the vascular cylinder (which remains thread-like). Lesions can occur on crowns of more succulent crops such as gloxinia. Above-ground symptoms include stunting, wilting and yellowing due to nutrient and water deficiencies.

Pythium black leg of cuttings is generally very black and often shiny.

Pythium spores germinate in response to root exudates. These provide food until the white, slender, profusely branching and rapidly growing mycelium penetrates the roots. See Figure 8-6. *Pythium Root Rot Life Cycle,* on this page. *Pythium,* depending on the species, quickly produces two types of spores:

- Asexual zoospores, which, when released, can swim in films of water until they contact healthy host tissue. There they germinate and start a new infection.
- Sexual oospores, which are thick-walled, resist both high and low temperatures, and remain viable for long periods of time.

Figure 8–6. *Pythium* Root Rot Life Cycle



Regardless of species, spores are moved around rapidly within a greenhouse in irrigation water.

Disease control

Pythium ultimum infections are most common at temperatures below 18°C, while other species favour high temperatures. Maintain temperatures favorable for plant growth, particularly root growth. High media temperature causes considerable root stress and is of concern during the summer months when growing on concrete floors and troughs.

Avoid overwatering and fertilization when the crop is young or not growing actively. Use a porous, well-drained media. Keep the EC of the media low during the summer. Check regularly for high salts. Avoid excess nitrogen fertilization.

Monitor and control fungus gnat populations. Both fungus gnat larvae and adults can spread the pathogen.

Rhizoctonia

Rhizoctonia solani is commonly associated with damping-off but can also occur in rooted cuttings and well-established plants of most commercial floriculture crops.

The symptoms vary with the host and development stage, but generally cause reddish-brown or black lesions on the below ground stem and roots of infected plants. Under favorable conditions, the lesions increase in size and number to include the whole base of the plant. See Figure 8-7. *Rhizoctonia Life Cycle,* on page 87.

This pathogen is slow to girdle the crown and root area of established plants. As a result, the grower may not observe this disease until long after the initial infection, when plants begin to wilt or appear stunted with yellowing leaves. Lower leaves of infected plants usually become chlorotic and plants may break off at the soil line.

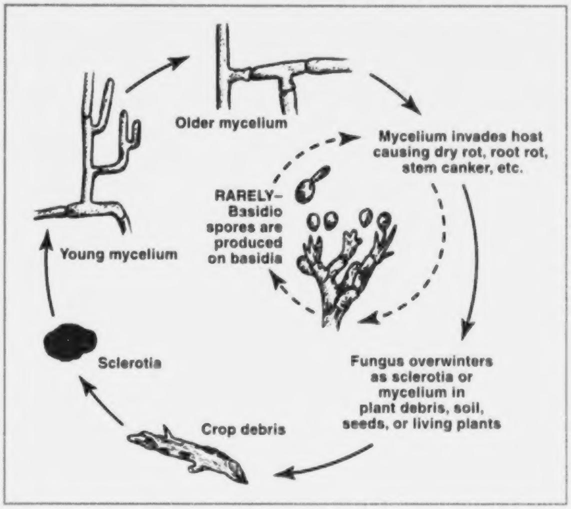
Potted plants propagated by cuttings are susceptible, such as geranium, poinsettia and New Guinea impatiens. It appears as a brown basal rot and stems may have longitudinal cracking. Crown rot can occur as a crown infection in the absence of root rot.

On fleshy, succulent stems, bulbs, and corms, the brown or black sunken lesions are often dry. Stem cankers can occur on lower branches where infested media have been splashed.

Disease control

High media and air temperatures and high RH promote *Rhizoctonia* in most greenhouse crops. Avoid wet and dry extremes in the growing media. Ensure good air circulation to quickly dry media surfaces. A temperature range of 17–26°C, which includes typical plant production regimes, is optimal for this pathogen.

Figure 8-7. *Rhizoctonia* Life Cycle


Older mycelium
Mycelium invades host causing dry rot, root rot, stem canker, etc.
RARELY– Basidio spores are produced on basidia
Young mycelium
Sclerotia
Fungus overwinters as sclerotia or mycelium in plant debris, soil, seeds, or living plants
Crop debris

Phytophthora spp.

Phytophthora causes root and crown rots (similar to *Pythium*) and occasionally leaf blights. In Ontario, these pathogens are most commonly observed during the summer growing period.

Two common species, *P. cryptogea* and *P. parasitica*, will attack many crops but the symptoms observed are similar. *Phytophthora*, like *Pythium*, is a water mould – the asexual spores and mycelium spread quickly in films of water.

Typical symptoms include necrotic brown to black lesions on larger roots and on the crowns. Basal cankers with black streaking often appear. Leaves can become infected by contact with infested media.

Zoospore production and development are stimulated by saturated media and root exudates.

Disease control

Avoid overwatering when the crop is young or not actively growing. Sub-irrigated crops may require routine overhead waterings to flush plant exudates from the medium. Use a porous, well-drained, pathogen-free growing medium. Avoid saturated media conditions. Water management is very important.

Avoid media temperatures above 26°C.

Ramorum blight and dieback (sudden oak death)

Ramorum blight and dieback is a serious disease caused by *Phytophthora ramorum* that has killed hundreds of thousands of oak trees in California and Oregon since first being detected in the mid-1990s. It has a wide host range with dozens of genera of plants (all species in each genus), including many common nursery-grown woody ornamentals, currently regulated by the CFIA. The disease has been detected in British Columbia but has been subject to an eradication program by the CFIA. Strict regulatory control measures are in place to ensure the disease does not become established in Canada. A wide range of symptoms are caused by the pathogen depending on the host, ranging from rapid decline and dieback of oak to foliar blights and leaf spots on rhododendron and camellia.

Evidence suggests that *P. ramorum* spreads by airborne spores and wind-blown rain. Cool temperatures with relatively high moisture favour disease development. Two mating types are known to exist: the A1 or European strain and A2 or North American type.
To view the latest phytosanitary regulations to prevent entry of this disease into Canada, visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA Inspection office (see Appendix D. *Other Contacts*, on page 131).

Fusarium spp.

Several *Fusarium* species cause stems, crowns, corms, bulbs and tubers to rot. The primary culprits are *F. solani* and *F. oxysporum*.

With root rots, the infected tissue is usually dark red to brown and may appear as streaks up to the soil line. Plant growth is usually retarded. As infection increases, the oldest leaves begin to yellow and younger leaves become flaccid.

In stem rots affecting plants such as chrysanthemum and carnation, the infected plants wilt and die from a dry stem rot at the base of the plant. The lesions that develop at or just below the soil line often have pink or red edges leading to the infections. The lesions develop inward. There is usually no external stem discolouration.

Bulb and corm rots can occur in the field and in storage. The rot usually begins at a wound or at the base of these organs and may not produce visible symptoms. However, the basal plate and fleshy scales will be brown and decaying, with mats of mycelium. The foliage often turns purple or yellow and dies prematurely.

Disease control

Crop stress, which is the leading environmental cause of *Fusarium* disease, predisposes plants to attack by this fungus. Standard disease control strategies apply. Review production practices and modify them as needed to minimize crop stress.

Maintain proper temperatures, avoiding high air and substrate temperatures. Avoid over-fertilization when crops are under stress.

Irrigate consistently. Wet or dry extremes enhance *Fusarium* development. Drought stress can result in the rapid onset of symptoms.

Use pathogen-free media. Use only new pots and trays to avoid contamination. Pasteurize the soil for effective control in soil-grown crops and use healthy, disease-free stock for vegetative propagation purposes.

Finally, use preventative fungicide applications during periods of unavoidable crop stress.

Thielaviopsis basicola

Thielaviopsis basicola causes a severe, black root rot of a number of major greenhouse flower crops. These include cyclamen, fuchsia, geranium, kalanchoe, primula, petunia, pansy, poinsettia and vinca.

Infected roots usually develop black lesions covering all or part of the root. Root tips may turn black. Plants are often stunted, with yellow or white leaves typical of a severe nutritional deficiency. The roots die rapidly, causing plant death.

Disease control

- Monitor the growing medium. *Thielaviopsis* thrives with high media moisture and a high pH. Cool media temperatures (15–16°C) favour development of this pathogen although optimum temperatures of 25°C have been reported.

- Avoid temperatures too high or too low for the crop. For example, do not grow vinca below 20°C.

- Avoid high ammonium nitrogen fertilization because the promotion of softer growth tends to make susceptible crops more prone to attack.

- Maintain proper sanitation practices and use only new containers for growing highly susceptible crops.

- Use pathogen-free media and maintain pH below 5.5. Avoid high moisture levels in growing media.

- *Thielaviopsis* is difficult to eradicate when crops are grown on the ground or wooden benches. Fortunately, this disease is not common.

Sclerotinia

Sclerotinia sclerotiorum attacks many herbaceous ornamental and vegetable crops, including chrysanthemum, snapdragon, salvia, dahlia, delphinium, tomato, pepper and eggplant. The disease is most common outdoors but is observed occasionally in the greenhouse.

Symptoms vary with the host, the affected host part and the environmental conditions. The most obvious early symptom is fluffy, thick, white mycelium on the stems of plants near the soil surface. See Figure 8-8. *Sclerotinia Life Cycle,* on page 89. Relatively large, hard, charcoal-black, resting fruiting structures (called sclerotia) soon appear. These are embedded in the mycelium or in the pith of plant stems. The fungus causes a stem rot, which eventually leads to wilting and death of the plant.

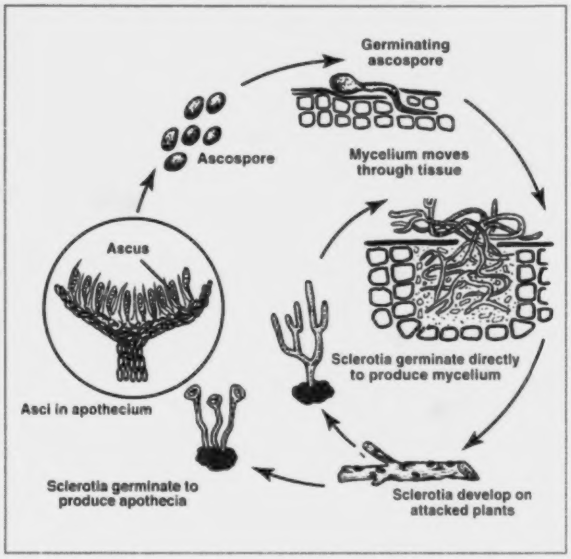
During the early infection stages, no visible signs of infection appear on the foliage until the fungus grows completely through the stem. The exception is when the initial infection occurs through a leaf.

Sclerotinia fungus survives either as sclerotia in the soil or on plant debris for at least three years, or as mycelium in dead or living plant material. Sclerotia are very resistant to extreme temperatures and moisture.

Disease control

Pasteurize the soil for effective control in soil-grown crops. For bench-grown crops, control can be difficult. Maintain dry foliage by minimizing overhead watering and dripping and provide good air circulation through the crop canopy.

Figure 8–8. *Sclerotinia* Life Cycle


Germinating ascospore
Ascospore
Mycelium moves through tissue
Ascus
Sclerotia germinate directly to produce mycelium
Asci in apothecium
Sclerotia germinate to produce apothecia
Sclerotia develop on attacked plants

This disease is most problematic in spring and summer because day length influences its activity.

Rusts

Rust fungi are obligate parasites and as such are specific to the greenhouse crop on which they are found. Some rusts found outdoors require an alternative host to complete their life cycle, however this is not the case for rusts found on greenhouse crops. Their life cycle is complex, producing up to five different spore types. Rust may occur on carnation, chrysanthemum, fuchsia, geranium, poinsettia, snapdragon and many outdoor perennials including columbine, daylily and rose.

Rust diseases produce masses of white, yellow, orange or brown to reddish-brown uredospores on the undersurface of leaves and stems. These appear when the pustules erupt to release the mature spores. First symptoms usually appear within 5–7 days of infection, depending on environmental conditions.

The various rusts can produce concentric ring patterns. These rings are due to a series of environmental conditions conducive to secondary and tertiary infections. The leaf surface directly above the pustule is usually yellow and may be sunken. Numerous infection sites on a leaf will cause yellowing and eventually senescence of the leaf. The lower leaves are usually infected first. Plants are rarely killed.

Cool temperature, high canopy relative humidity and plant density are critical to initial disease development and for secondary and tertiary infection that can typically occur.

Rust spores spread via air currents and by splashing water within a greenhouse. Spores can travel long distances on the leaf surfaces of cuttings. A film of water must remain on upper leaf surfaces for at least 3–4 hours for spore germination and infection; however, sporulation is on the undersurface.

Rust fungi survive as spores, as systemic mycelium on or in dormant plants and in plant debris.

Disease control

Chrysanthemum white rust is the only quarantinable rust disease of greenhouse ornamentals. Chrysanthemum white rust appears as creamy-coloured pustules on the undersurface of the lower leaves. For further information on the disease and the latest policy directive, visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA Inspection office (see Appendix D. *Other Contacts*, on page 131).

Growers who receive imported chrysanthemum stock from the United States that they suspect is infected must contact the Canadian Food Inspection Agency immediately.

Controlling rust diseases is difficult. Most produce more than one type of spore and infected plant residue (e.g. under benches) can harbour the spores for long periods.

A temperature range of 10–25°C favours spore production of most rusts and spores are released into the air more readily with diurnal relative humidity fluctuation.

Infections are often severe near fans and in corners of the greenhouse. Severe infections also occur under conditions of poor air circulation and temperature stratification due to crowding or a heavy canopy.

Avoid overhead watering or late-afternoon watering. Space plants to allow better air movement within plant canopies.

Prevent dew formation on plants by providing adequate heating, ventilation and air circulation at night to control relative humidity around and through the plant canopy.

Destroy all infected plants to reduce the inoculum level.

Bacterial Diseases

Bacteria are single-celled organisms that multiply rapidly under ideal temperature conditions. Their rate of development and spread increases with temperature, moisture availability and food supply.

Some plant pathogenic bacteria attack only one or two plant species, while others attack a wide range of plants. Plants commonly attacked by bacteria include geranium, begonia, chrysanthemum, calla lily and hibiscus.

Bacterial infections may appear as wilts, stem and root rots, leaf spots, galls and fasciation of plant parts. Although bacterial diseases are less common than fungal diseases, they can be very destructive and difficult to control. *Erwinia, Pseudomonas, Ralstonia* and *Xanthomonas* are the most common disease-causing bacteria affecting greenhouse crops. The bacteria can live on or in roots, on leaves and stems of hosts, and in non-host plants.

Bacteria do not produce spores. Most bacteria survive in the greenhouse in a semi-dehydrated state, infecting plant debris for extended periods of time. However, *Ralstonia* survives in soil without association with plant tissues for long periods of time. See more details in *Ralstonia solanacearum,* on page 91.

Bacteria enter wound sites and natural plant openings such as stomata and hydathodes or root hairs. A film of water is usually required for a bacterial infection to begin on above-ground plant parts.

With bacterial wilt infections, wilting of entire leaves or leaf margins is the first symptom. Infections typically become systemic very quickly, moving through the leaf veins and petioles. Entire leaves yellow or develop large, V-shaped yellow lesions. When bacteria invade the stems, the outside of the stem usually appears grey-black and water-soaked, while the internal stem tissue appears black.

Bacterial disease development is enhanced by high air and media temperature and by high relative humidity. Bacteria survive only in living or decaying plant material.

Pathogen spread during propagation is very common. Bacterial pathogens are spread by water movement through the media, water splashing and the physical movement of infected media and plant material within and between greenhouse operations.

Disease control

No chemical controls will eradicate bacterial diseases from infected plants in a production environment. Prevention is the key. Good cultural practices and careful sterilization procedures reduce the chance of bacterial infection.

Purchase disease-free stock from the plant breeder for propagation purposes and isolate stock plants in a thoroughly disinfected area. Disinfect cutting tools and propagation areas frequently.

In general, warm temperatures (above 25°C) are required for bacteria to develop rapidly and for plants to express symptoms.

Bacteria are spread on leaves and stems by condensation, splashing water, and during pruning or harvesting of cuttings. These diseases can spread very rapidly on propagation benches and in sub-irrigation systems.

Both fixed and organic copper sprays provide reasonable protection against bacterial diseases. However, they are not eradicants and may cause phytotoxicity.

Erwinia carotovora

Erwinia carotovora causes soft-rot symptoms that first appear to be simply water-soaked but quickly break down into a foul-smelling, mushy rot, resulting in complete collapse of the plant. This disease thrives in warm, humid conditions. Increased irrigation and high levels of both phosphorous and nitrogen promote its development. *Erwinia* is a ubiquitous bacterium in the natural environment.

Erwinia chrysanthemumi

Erwinia chrysanthemumi attacks a wide range of floral crops including all foliage crops, chrysanthemum, poinsettia and begonia. Its symptoms include root rots, leaf blights and wilts.

Ralstonia solanacearum

Ralstonia solanacearum is a bacterial plant pathogen that causes bacterial wilt. It has a very wide host range. Known previously as *Pseudomonas,* the bacterium is not really a new disease. Because of its diversity, it has been classified into various groupings known as Races and Biovars based on the host range and biochemical reactions. Of most concern is Race 3 Biovar 2, known as the "potato race", that was found on vegetative geranium cuttings originating from tropical or sub-tropical regions. It is of special concern because it has been shown to survive in soil in temperate climatic regions. *Ralstonia solanacearum* Race 3 Biovar 2 is a regulated, quarantinable pathogen in Canada and the United States. It was placed on the United States Department of Agriculture (USDA) *Agricultural Bioterrorism Act* of 2002, Select Agents and Toxins list. It is a regulated disease because it is not known to exist in North America and because its host range includes two important food crops, potato and tomato.

Growers who suspect this disease must notify the Canadian Food Inspection Agency immediately.

Ralstonia enters plants through the roots and through stem wounds. Race 3 is most severe between 24–35°C and decreases in virulence at very high or very cool temperatures.

Early symptoms are similar to bacterial blight. Lower leaves typically wilt first; sectorial leaf yellowing may be present and stems may show brown to black discolouration near the soil line. Eventually, the entire plant wilts and dies.

The bacterium will survive for long periods of time in soil without plant residue. Under greenhouse conditions the bacterium can be spread on cutting knives, in soil or in contaminated recirculating sub-irrigation systems.

It is thought the disease is easily spread via recirculating systems where pasteurization of the solution is not executed. In addition, the bacteria are spread by splashing water, plant-to-plant contact, infected tools and from contaminated clothing and hands of employees.

For the latest CFIA policy directives and disease fact sheet regarding *Ralstonia,* visit the CFIA website at *www.inspection.gc.ca* or contact your local CFIA Inspection office (see Appendix D. *Other Contacts,* on page 131).

Controlling this disease consists of quarantine and crop destruction.

Xanthomonas campestris pv.

Xanthomonas campestris and its various strains cause leaf spots and stem rots on a wide range of plants including begonia, geranium, zinnia and dieffenbachia. Symptoms range from small, well-defined spots with yellow margins on leaves to systemic activity where leaf veins become grey-green.

Infected leaves wilt and eventually turn yellow and die. Stems turn dark green as the bacteria block the vascular tissue. In geranium and begonia, distinctive yellow V-shaped areas bounded by major veins usually appear in many leaves. Initially, one branch of the plant may exhibit the symptoms.

Some hosts show no clear symptoms but may simply lack vigour.

Xanthomonas campestris pv pelargonii, commonly known as "bacterial blight", is very destructive in geranium. It infects all cultivars of zonal, ivy, seed and Martha Washington types. It is a systemic disease that can quickly kill zonal and seed geraniums. Other types are usually not killed but grow poorly and have an unthrifty appearance.

Viral Diseases

Viruses are disease-causing agents that multiply only within living plant cells. They tend to spread throughout the host plant through the vascular system. Many of the important horticultural crops belong to major plant families that are susceptible to viral attack.

With the introduction of many new vegetative annuals to the bedding plant industry, viruses have become of greater importance, particularly for those growers who also grow vegetable transplants. Viruses can be spread by sucking insects, such as aphids and leafhoppers, by tools, or by crop handling such as plant cleaning, disbudding or taking cuttings. Some viruses spread via infected cuttings.

Viral infection symptoms may include vein banding, flecking, ring spots, mosaic (irregular areas of dark and light green on the leaf) or growth abnormalities in the leaves. The specific symptoms depend on the type of virus. Symptoms do not always increase in severity. Some viruses cause stunting. In severely infected plants, the growing point of the plant may die.

The extent of the visible symptoms depends on the duration of the infection, the age of the plant at the time of infection and the crop growing conditions.

Disease control

No chemical controls will eradicate viral diseases. Prevention is the key. Good cultural practices and careful sterilization procedures reduce the chance of viral infection.

Purchase disease-free stock or cuttings from the plant breeder for propagation purposes. Isolate stock plants in a thoroughly disinfected area or screen vents and doors to prevent insect entry. Disinfect cutting tools and propagation areas frequently.

Crop stress predisposes plants to a virus attack. Symptoms will be more apparent in stressed plants.

Tomato spotted wilt virus/ impatiens necrotic spot virus

Tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV) are both tospoviruses, which are very unusual among plant viruses. The virus particles are quasispherical and are unique in that they are enveloped by a membrane composed of both lipid and protein. They are spread by only a few thrips species and have a broad host range. INSV is the most common in floricultural crops with TSWV usually affecting only chrysanthemum.

In Ontario greenhouse production, TSWV and INSV are transmitted only by western flower thrips. Unlike other insect vectors, thrips must feed on infected plant tissue as first instar larvae to acquire the virus. Virus transmission occurs when infective adults feed and continues for as long as the thrips are alive.

Characteristic symptoms vary depending on the host species and age. For many hosts, large brown or black circular concentric ring spots appear on the foliage. In many hosts, the virus becomes systemic, with black streaking of the major leaf veins, petioles and (in some plants) the stem.

In cyclamen, 8–10 weeks may pass between the initial infection and the first symptoms. Symptoms generally appear more quickly when plants are growing vigorously. When young gloxinias are infected, the virus rapidly develops systemically. Symptoms appear similar to *Phytophthora* crown rot. In other crops, such as petunia, the viral symptoms appear as small, discrete, tan-coloured spots. In petunia, the infection does not become systemic and this plant can be used as an early warning indicator of the disease.

Sometimes the symptoms mimic pesticide phytotoxicity.

Disease control

- A simultaneous, multi-pronged approach is necessary for successful control.
- It is impossible to control the virus during warm weather if viruliferous thrips populations are not controlled.
- Rogue virus-infected plants, stock plants and finishing plants to prevent first instar larvae from acquiring the virus.
- Control thrips populations to prevent viral spread. See Chapter 5, *Major Insect and Mite Pests,* on page 47, for detailed information on the life cycle of western flower thrips.
- Purchase only clean cuttings from reputable propagators.
- Isolate stock plants in a thrips-free area.
- Screen vents.
- Weed control is important, both inside and outside the greenhouse, as many weeds are reservoirs of the virus and western flower thrips.

9. Pesticide Application, Toxicity and Activity

Pesticide Application Effectiveness

When pesticide control fails, resistance is often suspected. However, resistance is not the most common cause of control failure, and a number of other factors should also be considered.

- Ensure that pesticide rates are calculated correctly and the product is measured accurately.
- Good coverage is needed for good pest control. Simple changes such as walking at a slower pace through the crop when applying pesticides, or walking every aisle instead of every other one, can significantly improve performance.
- Maintain spray equipment in good condition, changing spray nozzles on a regular basis. Older nozzles become worn, which can alter spray pattern and droplet size.
- Consider using different application technologies. High-volume, low-volume and electrostatic-spray application all have appropriate uses in the greenhouse.
- The biggest improvement in pesticide application may come from timing and targeting sprays more effectively. To accomplish this, implement an IPM program that provides the required information to decide when, where and why a pesticide application is needed. Sprays can then be applied where needed most (e.g. as spot sprays), when they will provide optimal control, and directly at the appropriate pest at the correct life stage.
- Pesticide effectiveness will vary (often considerably) between greenhouses, depending on factors such as the usage history of a particular product, the method of application, the time of application and the water quality.

Water for pesticide application

It is very important to lower the pH of alkaline water before using it for pesticide spray-tank mixtures. Adjust water pH to 5.5–6.0; at pH greater than 7, the pesticide may degrade rapidly. The rate of degradation depends on the pesticide, the concentration of pesticide in the tank (dilution factor) and the temperature of the water. To avoid the potential for pesticide degradation at higher pH, neutralize alkaline water before adding any pesticides.

Water-soluble fertilizers are used occasionally with pesticides as a tank mixture. In this case, it is important to choose acidic fertilizers, which make the further acidification of the water unnecessary. Do not use alkaline fertilizers for this purpose as it will be more difficult to neutralize the water and pesticide degradation may increase.

If it is not possible to acidify the spray water, try to use pesticides diluted with alkaline water (pH > 7) immediately.

Pesticide compatibility

Pesticides recommended in this publication are for individual application to a crop. Before mixing pesticides, read the product labels carefully for compatibility statements or contact the supplier. Avoid mixing emulsifiable concentrate formulations. Herbicides should never be mixed with fungicides and insecticides; apply with spray equipment reserved for herbicide use only.

Types of Pesticide Application

Spraying

Spraying is one of the most widely used and effective methods of applying pesticides. Clean and maintain nozzles to achieve a fine spray that will result in uniform coverage when the mixture is applied up to the point of runoff. Complete coverage is the objective; spray both the lower and upper leaf surfaces thoroughly.

Soil drenches

Soil drenches are used for both disease and insect control and involve the application of the pesticide to the root zone. The amount of pesticide added varies depending on the pot size and volume of the growing medium. To thoroughly wet the growing medium in a 15 cm pot requires approximately 150–180 mL. For soil beds, apply 12 L of drench per m². Be aware that not all pesticides require that the medium be completely wet, so follow the label directions carefully.

For disease control, drenches should not replace a thorough greenhouse pasteurization program but are useful for preventing recontamination or eliminating pathogens in the soil or the basal parts of the plant. Use a root inspection monitoring program as the first line of defence against root diseases.

Some drenches are taken up from the soil by plant roots and distributed throughout the plant. This is described as systemic action, and the whole plant is effectively treated against the pest or disease being targeted.

For insect control, drenches can be used for either soil-dwelling insects, such as fungus gnats and shore flies (controlling them by contact action), or for foliar feeding sucking insects, such as aphids and whiteflies (using systemically active products).

Thermal fogs

Thermal fogs are produced by several kinds of machines, all of which use heat from different sources to vaporize the pesticide. Fogging can be a very efficient method of pesticide application, but the machine needs to be well maintained.

Granular application

Several types of applicators are available for applying granular pesticides. Be sure the applicator does not grind or fracture the granules.

Insecticidal smoke applications

Smokes are a very simple but effective means of pesticide application. DDVP is the only registered pesticide available in a smoke applicator. There is no equipment involved; containers are simply placed on the path and lit. Do not use smokes in very old, poorly sealed greenhouses or during high winds.

Ultra-low volume

There are several types of ultra-low volume (U.L.V.) applicators available. They atomize the pesticide solution to an extremely small particle size (7–20 microns) and distribute pesticide through the greenhouse by a forced-air fan system.

Electro-static sprayers

Electro-static sprayers (E.S.S.) add an electrical charge to the fine spray particles. This enhances plant coverage by the pesticide and reduces drift.

Seed treatments

Seed treatments are pesticides that coat the seed, providing protection against pests or diseases during germination and early growth stages of the plant. See precautions when using seed treatments in Chapter 2, *Safe Use of Pesticides,* on page 7.

Wetting Agents

Wetting agents are classified as pesticides and need to be registered as such. In the following paragraphs, the term "wetting agent" includes spreaders, stickers and surfactants, although these terms have slightly different technical meanings.

Water will not always spread evenly over a surface. Its high surface tension means that when sprayed on a leaf (hydrophobic) surface, it forms large droplets that easily roll (with the pesticides) off the leaf and onto the ground.

Adding a wetting agent reduces the water's surface tension and allows the water to make better contact with the leaves. Consequently, the pesticides spread more evenly over the leaf surface. Most pesticides are formulated with a wetting agent in them. However, in some cases (due to air or water temperature, water hardness, type of leaf surface, stage of plant growth and/or the type of formulation), the amount may not be adequate. Consult the pesticide label for specific recommendations.

A simple method to determine if there is a sufficient amount of wetting agent is to spray approximately 3 m of bed area. Examine both the upper and lower surfaces of the leaves at different growth stages for evidence of uniform wetting. If wetting is not uniform, add 125 mL of spreader/1,000 L of spray. Spray another 3 m of the bed and re-examine; continue until wetting is satisfactory. Wetting agents help the spray solution wet powdery mildew mycelium, improving control. However, an excessive amount of wetting agent can cause plant damage and excessive foaming, which will cause pumping problems or runoff resulting in poor control.

Pesticide Toxicity and Classification

The toxicity, chemical family, pesticide grouping and Ontario classification of pesticides included in this publication are listed in Table 9-1. *Insecticide and Miticide Toxicity and Classification,* on this page, Table 9-2. *Fungicide Toxicity and Classification,* on page 97, Table 9-3. *Growth Regulator Toxicity and Classification,* on page 98, and Table 9-4. *Herbicide Toxicity and Classification,* on page 98. Products have been included in these tables if they are registered for use in greenhouse or outdoor ornamental crops. Read every product label to ensure suitability for a particular crop and use pattern.

Pesticide groupings are listed in the tables below for insecticides, fungicides and herbicides. They are used to differentiate the modes of action (MOA) based on classifications of the Insecticide Resistance Action Committee (IRAC), the Fungicide Resistance Action Committee (FRAC) and the Herbicide Resistance Action Committee (HRAC), e.g. how they work on the insect, disease or weed pest. The actual terminology that describes the MOA is complex and technical, so it is has been simplified by assigning numbers to the various MOAs in each group of pesticides. This information is important since resistance development in pests is often associated with a specific MOA. If resistance develops to a pesticide, the chances of cross resistance occurring with other pesticides with same MOA, are very high. Therefore, rotating between pesticides with different MOAs is an important strategy in managing the development of resistance. It becomes much simpler to do this by just referring to the pesticide group number to ensure that there is not excessive use of pesticides in the same group. Appendix F. *Pesticide Groups Based on Sites of Action,* on page 134, lists the insecticide and fungicide groups based on IRAC and FRAC classification. In addition, pesticide groups are also noted in Table 11-2. *Pesticide Recommendations – By Pest,* on page 116. This allows for a quick check of the pesticide groups available for each pest, making it easier to develop a rotational program.

Table 9–1. Insecticide and Miticide Toxicity and Classification

Common Name	Trade Name	*LD$_{50}$ (mg product/ kg body weight) unless stated otherwise	Chemical Family	IRAC Insecticide Group	Ontario Classification
Abamectin	Avid 1.9% EC	300	Avermectin	6	4
Acephate	Orthene 75 SP	1,494	Organophosphate	1B	3
Acequinocyl	Shuttle 15 SC	>5,000	Acequinocyl	20B	3
Acetamiprid	Tristar 70 WSP	1,064	Neonicotinoid	4A	3
Bacillus thuringiensis	Dipel 2X DF	>5,050	Biological	11	4
	Dipel WP	>4,000 (Technical)			4
	Thuricide	Not stated			4
	BioProtec 3P	Not toxic			4
	BioProtec CAF	Not toxic			3
	Vectobac 600L	>5,000			3
Beauveria bassiana	BotaniGard 22 WP,	>5,000	Biological		3
	BotaniGard ES	>5,000			
Bifenazate	Floramite SC	>5,000	Carbazate	Unknown	4
Carbaryl	Sevin T&O	642	Carbamate	1A	3
	Sevin SL	590			
	Chipco Sevin RP2	1,820			

* Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD$_{50}$ because of differences in concentration of the active and toxicity of inert ingredients. Where the LD$_{50}$ has been obtained using technical active ingredient instead of formulated product, this has been noted.

Table 9–1. Insecticide and Miticide Toxicity and Classification (con't)

Common Name	Trade Name	*LD_{50} (mg product/ kg body weight) unless stated otherwise	Chemical Family	IRAC Insecticide Group	Ontario Classification
Chlorpyrifos	Dursban Turf Dursban WSP Pyrate 480	135 382 409	Organophosphate	1B	3
Clofentezine	Apollo SC	>5,000	Tetrazine	10A	3
Cyromazine	Citation 75 WP	4,460	Triazine	17	3
Deltamethrin	DeltaGard SC	>15,000	Synthetic pyrethroid	3A	3
Diazinon	Diazinon 500E Diazinon 50W	1,600 66 (Technical)	Organophosphate	1B	3
Dichlorvos	DDVP Smoke 20%EC	56 56	Organophosphate	1B	3
Dicofol	Kelthane 50 W	3,060	dicofol	Unknown	3
Diflubenzuron	Dimilin 25 WP	>10,000	Substituted benzoylurea	15	3
Dimethoate	Cygon 480, Lagon 480	425	Organophosphate	1B	3
Endosulfan	Thiodan 4EC Thiodan 50 WP Thionex EC Thionex 50W	107 24 45 41	Organochlorine	2A	4
Fenbutatin oxide	Vendex 50W	>5,000	Organotin	12B	4
Imidacloprid	Intercept 60 WP	1,858	Neonicotinoid	4A	4
Kinoprene-S	Enstar II	1,649	Insect growth regulator	7A	4
Malathion	Malathion 25 W, 500 E Malathion 50	1,375 290	Organophosphate	1B	4
Metarhizium anisopliae (Strain F52)	Met52	Value not stated. Listed as very low toxicity	Biological		4
Mineral oil	Landscape Oil	>15,000	Horticultural oil		3
Naled	Dibrom	235 (Technical)	Organophosphate	1B	3
**Nicotine	Nicotine Smoke	Very toxic. Read MSDS.	Nicotine	4B	4
Permethrin	Pounce 384 EC Ambush 50 EC	1,030 2,280	Synthetic pyrethroid	3A	4
Phosmet	Imidan 50 WP	275	Organophosphate	1B	3
Potassium salts of fatty acids	Insecticidal Soap Opal Insecticidal Soap	Not toxic >5,000			4
Pymetrozine	Endeavor 50 WG	>5,000	Pymetrozine	9B	4
Pyridaben	Dyno-Mite 75 W	1,930	METI acaricides and insecticides	21A	4
Pyriproxifen	Distance	3,773	Juvenile hormone mimic	7C	3
Spinosad	Success 480 SC	>5,000	Spinosyn	5	3
Spiromesifen	Forbid 240 SC	>2,000	Tetronic acid	23	3
Tebufenozide	Confirm 240 F	>5,000	Insect growth regulator	18	3

* Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients. Where the LD_{50} has been obtained using technical active ingredient instead of formulated product, this has been noted.

**Nicotine registration is being phased out. Last date of sale by retailers is December 31, 2011 and last date of permitted use by growers is December 31, 2012.

Table 9–2. Fungicide Toxicity and Classification

Common Name	Trade Name	*LD_{50} (mg product/ kg body weight)	Chemical Family	FRAC Fungicide Group	Ontario Classification
Azoxystrobin	Heritage	>5,000	Strobilurin	11	3
Bacillus subtilis	Rhapsody ASO	>5,000	Biological	44	4
Captan	SupraCaptan 80 WDG Maestro 80 DF	>5,000 (Technical) >5,000	Phthalimide	M4	3
Chlorothalonil	Daconil 2787 Daconil Ultrex	4,200 >5,000	Chloronitrile	M5	4
Coniothyrium minitans	Contans	>2,500	Biological	Not classified	4
Copper	Phyton-27	Not stated	Inorganic	M1	4
Dazomet	Basamid Granular	519	Diazine		3
Dicloran	Botran 75W	>4,640	Aromatic hydrocarbon	14	4
Dimethomorph	Acrobat 50 WP	2,939	Cinnamic acid amide	40	3
Dodemorph acetate	Meltatox 40 EC	>2,000	Morpholine	5	4
Etridiazole	Truban 30 WP Truban 25 EC	1,077 2,404	Thiadiazole	14	4
Fenhexamid	Decree 50 WDG	>2,000	Hydroxyanilide	17	3
Folpet	Folpan 50 WP Folpan 80 WDG	>2,000 >5,000	Phthalimide	M4	4
Fosetyl-Al	Aliette T&O	2,860	Ethyl phosphonate	33	3
Gliocladium catenulatum	PreStop	>2,000	Biological	Not classified	3
Iprodione	Rovral 50 WP Rovral WDG	>5,000	Dicarboximide	2	3
Mancozeb	Dithane M-45	>5,000	Dithiocarbamate	M3	4
Metalaxyl	Subdue Maxx	2,965	Acylalanine	4	3
Myclobutanil	Nova 40 W	3,129 (Technical)	Triazole	3	3
**Oxine benzoate	No-Damp	>1,000 (Technical)	Aromatic hydrocarbon		4
Potassium bicarbonate	Milstop	2,700	Inorganic	Not classified	4
Propamocarb hydrochloride	Previcur N	>2000	Carbamates	28	3
Quintozene	Quintozene 75 WP	>3,670	Aromatic hydrocarbon	14	4
Streptomyces griseoviridis	Mycostop	>15,000	Biological	Not classified	4
Streptomyces lydicus	Actinovate SP	Non toxic	Biological	Not classified	4
Thiophanate methyl	Senator 70 WP	>6,000	Thiophanate	1	4
Trichoderma harzianum	RootShield Drench RootShield Granules	Non toxic Non toxic	Biological	Not classified	4
Trifloxystrobin	Compass 50 WG	>5,050	Strobilurin	11	3
Triforine	Funginex 190 EC	3,487	Piperazine	3	3
Zineb	Zineb 80 W	>1,850	Dithiocarbamate	M3	4

* Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients. Where the LD_{50} has been obtained using technical active ingredient instead of formulated product, this has been noted.

**No-Damp has been discontinued by the registrant. Product in the possession of the grower may be used legally until December 31, 2011.

Table 9–3. Growth Regulator Toxicity and Classification

Common Name	Trade Name	*LD_{50} (mg product/ kg body weight)	Chemical Family	Ontario Classification
Ancymidol	A-Rest	>5000	Pyrimidine	4
Benzyladenine + gibberellins A_4A_7	Fascination	>5,050	Cytokinin	4
Chlormequat	Cycocel Extra	2,836	Quaternary ammonium	3
Daminozide	B-Nine WSG Dazide 85 WSG	>5,000 >5,000	Organic acid	3
1-Methylcyclopropene	EthylBloc Technology	>5,000		2
Paclobutrazol	Bonzi Piccolo	>5,346 >2,000	Triazole	3
Uniconazole	Sumagic	>5,000	Triazole	3

* Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients.

Table 9–4. Herbicide Toxicity and Classification

Common Name	Trade Name	*LD_{50} (mg product/ kg body weight)	Chemical Family	Herbicide Group	Ontario Classification
Chlorthal dimethyl	Dacthal W75	>10,000	Phthalic acid	3	4
Dazomet	Basamid Granular	519	Dithiocarbamate	27	3
Fluazifop	Venture L	2,451	Aryloxyphenoxypropionate	1	2
Glyphosate	Roundup	5,400	Organophosphorus	9	4
Isoxaben	Gallery 75 DF	>5,000	Amide	21	3
Metolachlor	Dual Magnum	3,425	Chloroacetanilide	15	4
Napropamide	Devrinol 50 DF Devrinol 2G Devrinol 10G	>5,000 >5,000 >5,000	Amide	15	4
Propyzamide	Kerb 50 WSP	>5,000	Amide	15	3
Simazine	Princep Nine-T Simadex Simazine 480	>5,000 15,380 >5,000	Chlorotriazine	5	3
Trifluralin	Bonanza 480 Treflan EC Rival 500 EC	3,738 3,738 5,600	Dinitroaniline	3	4

* Figures obtained from the Material Safety Data Sheet (MSDS) for each product. Products with the same active ingredient can differ in LD_{50} because of differences in concentration of the active and toxicity of inert ingredients.

Fungicide Activity

Table 9–5. *Fungicidal Activity Against Diseases of Flower Crops* lists the activity of registered fungicides against greenhouse ornamental diseases.

Table 9–5. Fungicidal Activity Against Diseases of Flower Crops[1]

	Disease										
Fungicide	***Botrytis***	***Fusarium***	**Leaf Spot[2]**	**Powdery Mildew**	**Rusts**	***Pythium***	***Phytophthora***	**Downy mildew**	***Rhizoctonia***	***Sclerotinia***	***Thielaviopsis***
Acrobat (dimethomorph)								X			
Actinovate *(Streptomyces lydicus)*				S							
Aliette (fosetyl-Al)						X	X				
Botran (dicloran)	X										
SupraCaptan, Maestro (captan)	X		X			X					
Compass (trifloxystrobin)				X					X		
Contans *(Coniothyrium minitans)*										X	
Daconil 2787, Ultrex (chlorothalonil)	X	X	X	X	X				X		
Decree (fenhexamid)	X										
Folpan (folpet)						X	X				
Meltatox (dodemorph acetate)				X							
Milstop (potassium bicarbonate)				X							
Mycostop *(Streptomyces griseoviridis)*		S				S	S				
No-Damp (oxine benzoate)									X		
Nova (myclobutanil)				X	X						
Phyton 27 (elemental copper)	X		X	X							
PreStop *(Gliocladium catenulatum)*	S					S	S		S		
Previcur (propamocarb)						X	X				
Quintozene (quintozene)									X	X	
Rhapsody *(Bacillus subtilis)*	S		S	S							
RootShield *(Trichoderma harzianum)*		S				S			S		
Rovral (iprodione)	X								X	X	
Senator (thiophanate-methyl)	X	X	X	X					X	X	X
Subdue Maxx (metalaxyl)						X	X				
Sulphur			X	X							
Truban (etridiazole)						X	X				

[1] Growers should be aware that the level of control within individual production facilities may vary.

[2] Check label for specific leaf spot control. X – Denotes labelled diseases S – Denotes suppression

Pesticide Injury (Phytotoxicity) to Flower Crops

Although greenhouse pesticides have been selected and formulated to avoid plant injury, damage can still occur under some conditions. Consider these general rules before you apply pesticides:

- No product is safe on all plants under all conditions, although wettable powders are generally less injurious than liquid formulations.
- A material (e.g. smokes) may be safe when applied to dry foliage but can cause injury when used on wet foliage.
- Weather conditions at the time of application are important. Pesticides are more likely to be phytotoxic when applied during bright sunny weather than if applied during dull, overcast conditions.
- Well-watered, unstressed plants are less likely to be damaged by pesticides.
- Low-volume applications are generally less likely to cause plant injury than high-volume applications.

Pesticide hazards

The following list of possible hazards was compiled from grower experiences and pesticide label warnings. This list is not comprehensive. When using a product for the first time on a new crop, always test it first on several different varieties and on a small area and check for damage after 4–5 days.

- **Acrobat** may cause slight phytotoxicity to African violet, dusty miller, sweet alyssum and snapdragon after repeated applications.
- **Avid** may damage Shasta daisy and certain species of fern.
- **BotaniGard 22 WP** at higher application rates may result in commercially unacceptable visible residues. **BotaniGard ES** has been observed to cause foliage damage in some varieties of plants (e.g. tomatoes).
- Do not tank-mix **Botran** with EC formulations of insecticides, particularly organophosphates.
- Do not use **Chlorpyrifos (Pyrate)** on azalea, camellia, poinsettia, rose, geranium, oxalis, coleus or variegated ivy.
- **Compass** may cause injury to petunia, violet and New Guinea impatiens. If applied to poinsettia after bract formation, it may cause injury to bracts.
- **Daconil (2787 and Ultrex)** has been noted to cause discolouration of blooms on certain varieties of azalea, rhododendron, hydrangea and petunia.
- **D.C.D.** has been reported to cause damage to some greenhouse vegetable crops.
- **DDVP (dichlorvos)** is injurious to some older chrysanthemum varieties (e.g. Shasta and Pink Champagne) and some varieties of snapdragon. Crop should be dry when dichlorvos is applied as a smoke.
- **Dibrom** injures some ornamentals, including some rose varieties, and can damage tradescantia. Avoid over-treatment and direct application to plants.
- **Dimilin** should not be used on poinsettia, hibiscus or Rieger begonia.
- **Distance** has been observed to cause phytotoxicity on salvia, ghost plant *(Graptopetalum paraguayense)*, Boston fern, Schefflera and coral bells. Do not apply to poinsettia after bract formation.
- **Dursban WSP** should not be used on acalyphis, aphelandra, schefflera, croton, ficus, hibiscus, impatiens, nephrolepsis, petunia or rose.
- **Dyno-Mite** may cause colour change in blossoms of petunia (cv. White Madness).
- **Enstar II** application to some varieties of poinsettia has resulted in bract damage. Use on some varieties of roses can result in delayed damage.
- Do not use **Forbid** on orchids, *Pelargonium* spp., Peperomia or on "Attache", "Vogue" or "Classy" rose varieties or on "Noblesse" *Rosa floribunda*. Not recommended for use on alstroemeria, Cordyline, Dracaena, croton, neanthebella palm, schefflera, cyclamen, fuchsia, fern, *Hedera,* hydrangea, stock *(Matthiola)* or primula. Transient injury to flowers of Shasta daisy, begonia, snapdragon and Mexican

heather has been observed. Transient bleaching has been observed on some varieties of gerbera daisy. Do not apply more than once per crop to phlox, Shasta daisy, snapdragon, verbena, roses, gerbera daisy or marigolds.

- Do not use **insecticidal soap** on sweet pea, nasturtium or delicate ferns. Do not spray when plants are under stress or during full sun.

- Do not use **Malathion** on fern, petunia, crassula or African violet.

- Do not use **Meltatox** on Tropicana roses or on plants other than roses.

- **Nicotine** may injure tender plants and African violets.

- **Nova** may result in some growth regulation to treated plants.

- Rates of **Phyton 27** above 125 mL/100 L may damage tender, open blooms.

- **Rovral** can cause petal scorch on flowers of African violet.

- **Sevin (carbaryl)** should not be used on Boston ivy, Virginia creeper or maidenhair fern.

- **Shuttle** should not be applied to miniature roses and impatiens.

- **Subdue Maxx** may cause phytotoxicity on gloxinia when used as a drench at transplanting.

- **Thiodan (endosulfan)** should not be used on geraniums or Bonnafon chrysanthemums in the greenhouse or on chrysanthemum cuttings within one month of planting.

- **Vendex** should only be applied up until the tight bud stage of chrysanthemum and the pre-bract stage of poinsettias. Do not spray when plants are under stress or when the temperature of the greenhouse is greater than 32°C.

Agribrom

- Agribrom is registered for use as a water treatment to control algae.

- To be effective, it must be constantly present at a low level in the irrigation water.

- If irrigation water is being recirculated and Agribrom is added every time the water is reused, monitor chloride levels and suspend use if chloride levels are high.

- Treating reservoir water may also elevate chloride levels, so it is advisable to inject Agribrom just as the water is applied to the crop.

- Follow label directions carefully.

Pressure treated lumber

- Wolmanized® lumber is safe for greenhouse use.

- Copper napthanate has caused some crop injury to poinsettia.

- Other wood preservatives should not be used. Check with a Greenhouse Crop Advisor.

Prevent Bee Poisoning

While protection of bees is not relevant to most greenhouse flower growers, it is an important consideration for growers of outdoor flowers. Honeybees, as well as other bees and insects, are important pollinators of crops. Many crops also offer bees important sources of nectar for honey production.

If you choose to use insecticides for insect control, take these steps to prevent harming bees:

- Before you apply a pesticide, advise local beekeepers so they can move colonies out of the danger area. Contact the Provincial Apiarist at 1-888-466-2372, ext 63595 for a list of the beekeepers in the area.
- Do not spray any flowering crop on which bees are foraging. If you must apply insecticides, spray after 7 p.m. when the bees are not foraging. If this is not possible, spray before 7 a.m. Bees usually do not forage at temperatures below 13°C.
- Do not apply insecticide on windy days to prevent drift towards any nearby hives.
- When there is a choice, choose the product formulation that is less hazardous to bees. Dusts are more toxic than sprays; EC formulations are less toxic than WP formulations.

Most organophosphate and carbamate insecticides are highly toxic to bees. Examples of insecticides used in crop production that are toxic to bees are listed in Table 9-6. *Relative Toxicity of Pesticides to Honeybees*, on this page.

Read each pesticide label for specific precautions regarding bees.

Table 9–6. Relative Toxicity of Pesticides to Honeybees

Trade Name	Active Ingredient
Group 1 – Highly toxic. Do not apply to flowering crops or weeds outside the greenhouse	
Avid 1.9%EC	abamectin
Cygon 480, Lagon 480	dimethoate
DeltaGard	deltamethrin
Diazinon	diazinon
Dursban WDG, Dursban T, Pyrate 480	chlorpyrifos
Dyno-Mite 75 W	pyridaben
Imidan 50 WP	phosmet
Intercept 60 WP	imidacloprid
Malathion	malathion
Orthene 75 SP	acephate
Pounce 384 EC	permethrin
Sevin	carbaryl
Success 480 SC	spinosad
Group 2 – Moderately toxic. Apply only during late evenings or early morning*	
Endosulfan, Thiodan	endosulfan
Floramite SC	bifenazate
Pirliss 50 DF	pirimicarb
Supra Captan 80 WDG, Maestro 80 DF	captan
Tristar 70 WSP	acetamiprid
Group 3 – Pesticides relatively non-toxic to bees	
Aliette T&O	fosetyl-Al
Apollo SC	clofentezine
BioProtec CAF, Dipel 2X DF	*Bacillus thuringiensis*
Botran 75 W	dicloran
Bravo 500, Daconil 2787	chlorothalonil
Confirm 240F	tebufenozide
Decree 50 WDG, Elevate	fenhexamid
Funginex DC	triforine
Kelthane 50W	dicofol
MilStop	potassium bicarbonate
Nova 40 W	myclobutanil
Rhapsody ASO	*Bacillus subtilis*
Rovral 50 WP	iprodione
Senator 70 WP	thiophanate-methyl
Shuttle 15 SC	acequinocyl
Subdue Maxx	metalaxyl

* Unusually low temperatures at time of application may cause insecticides to remain toxic up to 20 times longer than during warm weather. High temperatures in the early morning or late evening may extend active foraging by bees.

10. Using Plant Growth Regulators

Plant growth, especially vegetative growth, can be controlled by a number of cultural and environmental management strategies, as well as with chemical plant growth regulators (PGR). PGRs are chemicals that modify the natural hormonal activity that controls plant growth and development. The cultural and environmental factors that influence plant growth and development can also influence how a crop responds to a PGR. Most of the PGRs used in the greenhouse function as "growth retardants". These PGRs reduce plant height by inhibiting the production of gibberellins, which are the hormones responsible for cell elongation. Their effect is primarily on stem, petiole and peduncle elongation. Leaf expansion may be reduced, resulting in smaller, thicker leaves with darker green colour.

Achieving the best plant response to PGRs requires integrating both the art and the science of growing. PGRs are not a substitute for good crop management practices and accurate environmental control.

Cultural Factors Influencing Plant Growth

Moisture stress

Growing a crop under moisture stress, which can be accomplished by withholding water within the growing substrate as well as maintaining very low relative humidity, will reduce plant growth.

Nutrition

Fertilizing with ammonium-based nitrogen promotes cell expansion and ultimately stem elongation. With many plant species, use of low (or zero) phosphorous fertilizers will reduce plant height without adversely affecting flowering. Thus, once plants are established, fertilizers such as 15-0-15 are recommended to control vegetative growth.

Average day (24-hour) temperature

Raising or lowering the average 24-hour temperature has an impact on plant height. For example, roses and "cool" crops such as anemones, ranunculus, primula and cineraria will remain short when grown at higher temperatures, while crops such as chrysanthemums and lilies are generally taller when grown at higher temperatures. Raising or lowering the average 24-hour temperature will increase or retard the rate of plant development.

Day/night temperature or DIF

DIF is defined as the day temperature minus the night temperature. The maintenance of a lower day than night temperature (negative DIF), or the provision of a sudden temperature drop to 12–13°C for 2–3 hours beginning at dawn, reduces stem elongation. This change influences gibberellin synthesis.

Light intensity

Higher light intensities generally produce shorter plants in the greenhouse.

Light quality

The effect of end-of-day light quality on stem elongation is similar to the DIF effect. The ratio of red to far-red light (photomorphogenic light) affects stretching and branching. Removal of end-of-day twilight from the greenhouse through the use of blackout curtains increases the red/far-red light ratio compared to ambient light, and is an effective technique to produce shorter plants.

Mechanical stress

Plants regularly brushed or vibrated a number of times per day will be shorter in height.

Cold water

Use of cold water applied overhead and trapped in the growing point can have a growth-regulating effect on some plants. For Easter lily (cv. Nellie White), it has been shown that plant height increases linearly with water temperature at a rate of approximately 1.5 cm/°C in the range of 2–20°C. In this situation, 100 mL of water was applied two times a week. The water must be applied onto the meristem (apical point) of the plant rather than on the soil. Some bedding plants also respond positively to this technique.

Plant Factors Influencing Plant Growth

During the last three decades, plant growth regulators (PGRs) have become an important cultural tool in modifying plant development in greenhouse flower crop production. They influence different plant processes, such as stem elongation, branching, rooting, flower induction and vegetative growth. This section focuses on factors to consider when limiting vegetative growth (controlling height) using PGRs.

Plant vigour

Provide PGRs only to vigorously growing plant species and/or vigorous cultivars. Rates that are effective on one cultivar may be too high or too low on another of the same species. Avoid using PGRs or use lower rates on less vigorous cultivars, as height reduction may be excessive. PGRs impose a stress on plants and healthy, vigorous plants are more likely to tolerate this stress. A dehydrated plant is more susceptible than a turgid plant to phytotoxicity from a PGR. Apply PGRs only to plants with well-established root systems. For example, A-Rest applied to Easter lilies with poor root development can cause undue loss of bottom leaves.

Species and cultivar response

Not all species respond to all PGRs. The growth habit of a cultivar determines the PGR concentration and the number of applications required. For example, a vigorously growing potted chrysanthemum or verbena will generally need a higher concentration of PGRs than shorter or more compact cultivars. The same is true for most flowering plants including poinsettia, kalanchoe and geranium.

Stage of plant growth

PGRs are most predictable when applied to young plants. Improper timing may delay flowering or severely stunt plant growth. For example, Sumagic when applied at too high a rate will result in lilies with a palm tree effect, or when applied to poinsettia after the beginning of short days, bracts may be too small. Early application may affect the development of some (bottom) breaks on poinsettia and chrysanthemum. This is most pronounced with high rates of systemic PGRs.

Plant size

Plant size impacts PGR application. Smaller plants require lower rates or less chemical than larger plants. Bedding plant plug seedlings require lower rates and volumes compared with flats or larger containers. Lower rates are usually recommended for young plants when the growing media is not covered with foliage, especially when the PGR has root uptake activity.

Environmental Factors Influencing Plant Growth

Plants grown under low temperature and light may require fewer PGR applications than those grown under higher light and temperatures. Adjust concentrations accordingly for winter and summer production especially when using the more active or stronger PGRs such as Bonzi/Piccolo or Sumagic. Do not apply PGRs when temperatures exceed 26°C. If possible, apply during the evening or during periods of low transpiration losses so the plant tissue can absorb the PGR. This is particularly true for contact PGRs such as B-Nine/Dazide and, to a lesser extent, Cycocel Extra. Bonzi/Piccolo and Sumagic are systemic PGRs that are quickly absorbed within the plant tissue.

Weather conditions directly influence absorption of the PGR following application and may affect results. Light and temperature conditions that favour rapid drying of spray droplets on foliage decrease the effectiveness of the water soluble PGRs, B-Nine/Dazide and Cycocel Extra, since less chemical is absorbed. Apply these products late in the day, during cloudy weather, and/or close the shade cloth when spraying to maximize chemical uptake. Avoid wetting the foliage of plants sprayed with B-Nine/Dazide and Cycocel Extra for at least 18 hours.

Use lower labelled rates and less volume per unit area during low light periods of the year when plant vigour is reduced.

Physical and Chemical Factors Influencing Plant Growth

Residual chemical effect

The length of time a PGR remains active in the plant after application varies. PGRs such as B-Nine/Dazide and Cycocel Extra lose most of their activity after 1–2 weeks. A-Rest, Bonzi/Piccolo, Sumagic and Fascination remain active in the plant for at least 3–4 weeks, but duration is dependent upon environmental factors. Bonzi/Piccolo and Sumagic can remain active in the growing medium for a long time.

Chemical uptake and translocation

Spray applications of Sumagic and Bonzi must be directed at the stems. Although these chemicals are readily absorbed by leaf tissue, they are not effective when applied only to the leaves because there is minimal movement from the leaf tissue to other parts of the plant.

B-Nine is slowly absorbed across the cuticle layer and has no systemic activity.

Fascination does not disperse well within the leaf and so uniform spray coverage is essential. Avoid runoff on to growing media because Fascination moves into the plant through the roots, causing excessive stem elongation.

Smaller spray droplet size usually improves coverage and increases the efficacy.

With regard to drench applications:

- Bonzi/Piccolo and Sumagic are actively taken up by roots and translocated to shoot tips.
- A-Rest is readily absorbed and translocated from roots, stems and leaves.
- Cycocel Extra is not readily absorbed by roots compared with Bonzi/Piccolo, Sumagic and A-Rest, therefore the labeled rates to effectively control stem elongation are much higher. Cycocel Extra is only registered as a media drench in Canada.

Dosage and coverage

For most PGRs, the concentration of the active ingredient (a.i.) in the solution to be applied is critical. For simple conversion on a normalized level (1 or 1,000 ppm a.i.), see Table 10-1. *Dilution Guidelines for PGRs,* on page 106.

Measure accurately using proper weighing instruments and/or measuring containers. For A-Rest, the recommendation is for drenching and is expressed as total active ingredient (a.i.) per pot. This means that the solution concentration (mg/1000 mL or ppm) multiplied by the solution volume to be applied (mL/pot) should equal the dosage (mg/pot).

Coverage refers to the volume of solution sprayed per unit area, or for drenching, the volume of solution per pot size or area (if applied to soil beds).

Always read the label. There may be different formulations on the market or the formulation may have changed. Use the material according to the manufacturer's directions. The label may also indicate the need for a spreader sticker.

Store PGRs in a cool, dry, dark place. Do not allow temperatures to drop below 0°C. Shelf life is at least two years. Note that some PGRs may become unstable over time or less effective when mixed with high pH water. To prevent breakdown, mix just before using or acidify the water to a pH below 6.0.

Application method

Drench

Drench treatment is more precise than spraying but generally requires more labour unless applied through the irrigation system. Some PGRs (e.g. A-Rest, Bonzi/Piccolo and Sumagic) are systemic. They are actively taken up by roots and transported to the shoot tips. Cycocel Extra is only effective when drenched at high rates. Drenching may distribute the chemical more evenly within the plant and increase growth regulation. Drenches generally have less effect on flower size, flower delay and tend to provide longer control than sprays. Drenches can be applied more evenly than sprays because the volume per container is more easily measured. The drench volume is adjusted to reflect pot size.

Drench applications of Sumagic and Bonzi/Piccolo are extremely effective, however accuracy is critical.

Table 10–1. Dilution Guidelines for PGRs

Product Name	Active Ingredient	Formulation	Spray or Drench Solution	
			1 ppm	1,000 ppm
A-Rest	ancymidol	0.0264% (0.264 g/L)	3.8 mL/L	
B-Nine	daminozide	85 WSG (850 g/kg)		1.2 g/L
Dazide	daminozide	85 WSG (850 g/kg)		1.2 g/L
Bonzi	paclobutrazol	0.4% (4 g/L)	0.25 mL/L	
Piccolo	paclobutrazol	0.4% (4 g/L)	0.25 mL/L	
Cycocel Extra	chlormequat	46.0% (460 g/L)		2.2 mL/L
Fascination	benzyladenine + gibberellins A_4A_7	1.8%/1.8%	0.056 mL/L	
Sumagic	uniconazole	0.055% (0.55 g/L)	1.8 mL/L	

Be sure roots are well developed before drenching with any PGR. The growing media must be moist when making a drench application. Apply adequate amounts of solution to wet the entire root mass. Be sure plants are not stressed. Injury can occur if plants are even a little dry. It may be wise to water the plants in late afternoon and apply the treatment the following morning. Another benefit of pre-watering is to have a more even distribution of the PGR throughout the substrate in the pot.

The only PGR registered for use through sub-irrigation is Piccolo. When applied through sub-irrigation reduce rates by up to 50%. Do not reuse pots trays or other containers that previously held plants or growing media treated with Sumagic and Bonzi/Piccolo. Be aware of possible residues remaining on flood tables, floors or troughs when these PGRs are used.

Pine bark–based mixes will reduce the effectiveness of A-Rest, Bonzi/Piccolo and Sumagic.

Spray

Spray application is often easier than a drench application, but ensuring uniform foliage coverage is critical. Spraying equipment must be operating properly.

The volume applied per unit area varies depending on the age and size of the crop. The spray volume on the label reflects a typical crop with plants at different stages of development. The application approach will vary depending on the PGR.

Because Bonzi/Piccolo and Sumagic are absorbed primarily through plant stems, penetration of the plant canopy to get uniform coverage of the stems is important. They are very readily adsorbed to the growing media making the active ingredient available for root uptake. It is important to avoid over spraying.

Most chemicals contain wetting agents. However, a spreader may be necessary to distribute the chemical uniformly on the foliage and lessen the likelihood of leaf damage. A rate of 10–20 L of spray/100 m^2 will generally give good coverage. For young and small plants, an even smaller volume should be used. To prevent chemical wastage, arrange the plants as closely together as possible without undue crowding.

Keep a separate sprayer for applying PGRs. Clean the sprayer after each application to prevent unnecessary damage from other chemical residues.

Use the recommended spray volume in Table 10-2. *Recommended Application Volumes,* on this page, as a guide.

Table 10–2. Recommended Application Volumes

Pot Diameter (cm)	Volume of Solution (mL/pot)	
	Drench	Spray
10	90	3
13	120	6
15	180	10
20	240	17.5
25	300	25

When applied as foliar sprays, PGRs must be absorbed and/or transported within the plant. The active ingredient must move through the waxy cuticle layer of the leaf or stem and then into the plant tissue. Highly water-soluble PGRs such as B-Nine/Dazide and Cycocel Extra move slowly through the cuticle, while less-soluble PGRs (Sumagic, Bonzi/Piccolo, A-Rest) penetrate very rapidly.

Plants should be turgid to prevent foliage damage. For Cycocel Extra and B-Nine/Dazide, absorption occurs while the foliage remains wet, which means they must be applied in the early morning, at the end of the day or under cloudy, humid conditions with lower air movement. For these products, avoid overhead watering for 12–24 hours and keep the plants dry, so that the active ingredient is not washed off the plant.

A-Rest, Sumagic and Bonzi/Piccolo are absorbed very rapidly (within minutes), with little potential for being washed off after drying.

Number of applications

While a single drench or spray application may be the most economical, a single application treatment at the highest labeled rate often can result in over application resulting in excessive plant growth regulation. Rate of application is very dependent on light, temperature, relative humidity and watering and fertilization practices. A split application using the lowest recommended rate (usually half of the highest recommended rate) applied twice is a safer alternative. A 1–2 week interval between applications increases flexibility and reduces the chance of plant damage. It also allows time to monitor plant growth, take weather changes into account and make repeated applications accordingly. Plant shape generally improves with the technique of multiple applications.

Estimating Final Plant Height

Floriculture researchers have found that the final height of chrysanthemum, Easter lily and poinsettia can be predicted using growth charts over time (graphical tracking). Graphical tracking can help determine the effectiveness of a growth retardant and the need for additional applications. Four weeks following the start of short days, chrysanthemum and poinsettia reach approximately half their final height at maturity. Easter lilies will approximately double in height from the time of visible bud. Measuring the plant height from the pot rim at this time and doubling this number provides an estimate of the final height. If the four-week estimated height is too tall, an additional PGR may be warranted. This will reduce growth further and produce a more desirable plant.

Growers should use graphical tracking in an integrated cultural program as a growth-monitoring technique. Graphical tracking programs are commercially available with typical growth curves for these crops.

Directions for Mixing Plant Growth Regulators

Always read the label. Handle the chemicals according to the manufacturer's recommendations and observe all restrictions and precautions.

When mixing chemicals, note that the final volume of a PGR mixture should include the PGR that will be added. First measure the chemical, then add about half of the required water to the tank followed by the measured chemical, followed by more water until the desired final volume of the solution is reached. For example, if the label directions read 60 mL B-Nine/Dazide per L, first add 0.5 L of water, then add 60 mL of B-Nine/Dazide to a suitable measuring container, before adding more water to the 1 L mark. Remember that the final solution, including the B-Nine, should be 1 L. Agitate well before and during spraying.

Do not add wetting agent (spreader) if the label states that this is already present in the solution. However, if excessive beading occurs, add wetting agent to eliminate the beading.

Read the label to see if the material is sufficiently stable for storage after mixing. It is best to mix PGR products right before each application to ensure proper chemical activity.

Do not mix PGRs with other pesticides. Growth regulator applications are too critical; do not take chances to save time. Mix and apply PGRs precisely.

Growth Regulator Recommendations for Flower Crops

The effectiveness of PGRs can be very crop dependent. Read the label before applying any PGR. See Table 10-3. *Summary of PGRs by Crop,* on this page and Table 10-4. *Plant Growth Regulators,* on this page.

Table 10–3. Summary of PGRs by Crop

Crop	Registered PGRs
All cut flower, flowering potted and foliage crops	EthylBloc Technology
Azalea	B-Nine/Dazide
Bedding plants	B-Nine/Dazide, Bonzi/Piccolo, Sumagic
Chrysanthemum (pot)	A-Rest, B-Nine/Dazide, Sumagic
Chrysanthemum (cut)	B-Nine/Dazide
Geranium (zonal)	Bonzi/Piccolo, Cycocel Extra, Sumagic
Hydrangea	B-Nine/Dazide
Easter lily	A-Rest, Fascination, Sumagic
Lily hybrids	A-Rest, Fascination
Poinsettia	A-Rest, B-Nine/Dazide, Cycocel Extra, Sumagic

Table 10–4. Plant Growth Regulators

A-Rest (264 mg/L or 0.0264% ancymidol)	
Crops	Chrysanthemum (potted), lily, poinsettia
Concentration of active ingredient	2–8 ppm
Mixing rate	2 ppm = 7.5 mL per L final solution 8 ppm = 30 mL per L final solution
Method of application	Drench. Apply 0.25-0.50 mg active ingredient per 15 cm pot.
Timing	• *Chrysanthemum:* Apply just as root system spreads over outside of root ball, or approximately 2 weeks after pinch when laterals are 5–10 cm long. • *Lily:* Apply when lily is 7–15 cm tall. Do not apply between Jan. 23 and Feb. 7, as bud count may be reduced. • *Poinsettia:* Treat plants from pinch to 4 weeks after pinch, or 8–12 weeks before finish. Do not apply after bract initiation has begun.
Comments	• Entire soil must receive uniform application. Do not apply a wetting agent. Ensure healthy roots and adequate phosphorus nutrition of Easter lily to minimize lower leaf yellowing.

Table 10–4. Plant Growth Regulators (con't)

Cycocel Extra (46.0% chlormequat)	
Crops	Geranium (zonal), poinsettia
Concentration of active ingredient	*Geranium:* 1,500–3,000 ppm *Poinsettia:* 1,500–3,000 ppm
Mixing rate	1,500 ppm = 3.25 mL per L final solution 3,000 ppm = 6.5 mL per L final solution
Method of application	Drench
Timing	• *Geranium (zonal):* Apply as a drench at 1,500–3,000 ppm 3 weeks after transplanting, when well-rooted and stem begins to elongate. • *Poinsettia:* Apply when shoots are 2–4 cm tall.
Comments	• *Geranium (zonal):* Application induces earlier flowering and promotes branching. • *Poinsettia:* Application later than Oct. 15 for poinsettias, grown under natural photoperiod, may delay flower development and reduce bract size. Drenching twice with half the recommended concentration results in better plant quality than once at a high concentration.

B-Nine WSG/Dazide 85 WSG (85% daminozide)	
Crops	Azalea, bedding plants, chrysanthemum (potted and cut), hydrangea, poinsettia
Concentration of active ingredient	*Azalea* (1,500–2,500 ppm) *Bedding plants* (5,000 ppm) *Chrysanthemum* *pots* (2,500–5,000 ppm); *cuts* (2,500 ppm) *Hydrangea* (5,000 ppm) *Poinsettia* (5,000–7,500 ppm)
Mixing rate	1,500 ppm = 1.8 g/L final solution 2,500 ppm = 3.0 g/L final solution
Method of application	Spray 2–4 L/100 m^2 of bench area. A crop with larger leaf area will increase volume required to be applied. Spray to run-off.
Timing	• *Azalea:* Apply after last pinch when shoots are 2.5 cm long to promote development of additional buds (1 application at 2,500 ppm or 2 applications at 1,500 ppm, 1 week apart). • *Bedding plants:* Apply 2–3 weeks after transplanting or when the plant shoots begin to elongate. Repeat as required. • *Chrysanthemum (pots):* Apply about 2 weeks after pinching when shoots are 2–4 cm long. May be repeated 3 weeks later; • *(Pots & cuts):* To prevent stretching of the peduncles, spray 2 days after disbudding or 4 weeks after shade initiation. • *Hydrangea:* Apply first spray between 2 and 3 weeks (4–5 leaf stage), second spray one week later. • *Poinsettia:* Spray when shoots are approximately 5 cm tall. Spray concentration depends on pinching date (which depends on pot size). Vigorous plants may need a second application.
Comments	• *Azalea:* Application increases short-day response and early bud formation. Do not let solution drip onto growing medium. • *Bedding plants:* As a PGR it is effective on most bedding plants but ineffective on snapdragon, celosia, coleus, pansy, geranium, carnation, cleome, convolvulus and gomphrena. • *Chrysanthemum (pots):* Use low concentration on pinched crops, high concentration on single-stem plants. Spray foliage to run off; *(Cuts):* Do not mix B-Nine with other pesticides. • *Hydrangea:* Apply after buds are visible if necessary. • *Poinsettia:* Do not add any wetting agent. Application made after initiation of short days will delay blooming. • Do not wet foliage for 18–24 hours following application.

Table 10–4. Plant Growth Regulators (con't)

Bonzi/Piccolo (4 g/Lpaclobutrazol)	
Crops	Container grown ornamental bedding plants in plug trays, cell packs, or pots
Concentration of active ingredient	0.5–60 ppm depending on method of application and crop species. *Read the label carefully. Paclobutrazol is extremely active at very low concentrations. Test with lower concentrations on all species and cultivars.*
Mixing rate	1 ppm = 0.25 mL per L final solution 2 ppm = 0.5 mL per L final solution 10 ppm = 2.5 mL per L final solution
Method of application	• Spray (use 1–2 L per 10 m^2 of bench area for small plants in plug trays depending on the stage of plant growth). • For plants with well developed canopy, 3 L/10 m^2 may be required. • Drench (use 60–80 mL per 10 cm pot; 120–140 mL per 15 cm pot).
Timing	• For bedding plant plug seedlings, make first application at the first- or second-leaf stage. Apply to plants in cell packs or pots once plants are established after transplanting, usually 2–3 weeks later. • Apply when flower stems begin to elongate to reduce late stretch of peduncles.
Comments	• Bonzi/Piccolo spray applications are absorbed through the stems, so thorough and uniform coverage is essential. Over-application can result in stunting and delayed flowering. • Desired height control is usually obtained with a single spray or drench application, but good height control can also be obtained by repeated applications 7–10 days apart at half the recommended concentration, particularly under lower light and temperature conditions. • High spray rates may delay flowering. • Take care not to apply excessive amounts of spray to young plants that have not completely covered the medium; excess may enter the medium and act as a drench, resulting in excessive stunting of sensitive species. • Drench applications tend to be most effective in controlling plant height and producing a uniform effect. Application can be made near marketable size without phytotoxic effect. • Apply only to moist growing media. Media containing bark may require higher application rates. Do not reuse pots or trays that had plants or soil treated with Bonzi/Piccolo. • When applying Piccolo through sub-irrigation, reduce rates by 25–50%.

Fascination (1.8% benzyladenine, BA, and 1.8% gibberellins, GA_{4+7})	
Crops	Easter lily, Asiatic hybrid lily, oriental hybrid lily and asiflorum hybrid lily
Concentration of active ingredient	25–100 ppm of benzyladenine and GA_{4+7}
Mixing rate	25 ppm = 1.4 mL per L final solution 100 ppm = 5.6 mL per L final solution
Method of application	• Easter Lily – Direct spray at 25–100 ppm to the lower leaves only at visible bud stage, before leaf yellowing starts. • Asiatic, Oriental, asiflorum lilies – Apply to entire plant at 50–100 ppm when buds are fully formed and one day before being placed in cold storage to delay flower senescence. • Use standard equipment at low pressure to avoid misting the immature leaves and stem, which will cause stretching of plants. Apply 1.9 L of spray solution to 10 m^2 of bench area; ensure proper coverage of lower leaves but no more than 15 mL per plant, as soil application can also cause stretch. The product is not systemic so only leaves contacted will be protected from leaf yellowing.
Timing	Apply at visible bud stage or just prior to cold storage.
Comments	• Differences in plant response due to differences in plant surfaces, leaf orientation and plant structure are possible. Apply during morning or late afternoon, when plants are not under stress. • Avoid direct contact to immature leaf as it will result in unwanted stem elongation.

Table 10–4. Plant Growth Regulators (con't)

Sumagic (0.055% uniconazole-P)

Crops	Bedding plants, chrysanthemum, Easter lily, geranium (seed and zonal), poinsettia
Concentration of active ingredient	*Bedding plants:* 1–30 ppm *Chrysanthemum:* 5–10 ppm *Easter lily:* 3–30 ppm *Geranium:* 2–4 ppm (seed); 2–8 ppm (zonal) *Poinsettia:* 2–8 ppm
Mixing rate	1 ppm = 1.8 mL per L final solution 2 ppm = 3.6 mL per L final solution 10 ppm = 18 mL per L final solution
Method of application	• Spray (use 1–2 L per 10 m² of bench area depending on the stage of plant growth). • Low pressure and larger droplet size are recommended for best results.
Timing	• *Bedding plants:* Timing varies depending on the species being treated. Read the label carefully. First application is usually made when seedlings are 2.5–3.0 cm tall. • *Chrysanthemum:* Apply 7–14 days after pinch when the length of the breaks is 3.8–5.0 cm. A single repeat spray can be made 7–21 days after the first, to increase the level of growth reduction. • *Easter lily:* Apply when shoots are 7.5 cm tall. Do not make repeated applications within 2 weeks and avoid late applications. • *Geranium: (seed)* Apply when plant height is 5–16 cm; *(zonal)* Apply to cuttings once rooting is established. • *Poinsettia:* Apply when breaks are 3.5–5.0 cm long (about 10–14 days after pinching). Up to two repeat applications can be made at 7-day intervals until desired growth characteristics are achieved. Do not apply once the initiation of bracts has begun.
Comments	• Plant response to Sumagic is strongly influenced by cultural and environmental factors such as growing media, water/fertilizer management, temperature, light, greenhouse structure and other cultural practices. Treat a limited number of plants at the lowest recommended rate when using for the first time. Lower rates may be needed at lower temperatures. • *Bedding plants:* Use the lowest recommended rate. Check response of each species and cultivar first on a small group of plants as per label directions. • *Chrysanthemum:* Two applications may have more effect than the same amount of product applied as a single treatment. • *Easter lily:* Treatment with Sumagic may reduce the water requirement of Easter lily. Avoid late-season applications. Under Ontario conditions, the rate of 2–3 ppm seems suitable with a maximum of three sprays per season. • *Poinsettia:* Bract size and diameter may be slightly reduced with treatment, and days to flowering may be delayed if applied after the initiation of short days.

EthylBloc Technology (0.14% 1-Methylcyclopropene)

Crops	Registered for use on cut flowers, potted flowers and foliage plants as a post-harvest treatment to protect against the effects of ethylene.
Concentration of active ingredient	• Apply 0.25 or 0.5 g/m³ depending on treatment time and storage temperature. • Read label carefully when selecting rate of application.
Method of application	• Place EthylBloc Technology water soluble packets (based on volume of treatment room) in water to dissolve and begin the release of the 1-MCP vapour (gas) within tightly closed storage rooms or containers under both refrigerated and room temperatures.
Timing	• Make single application immediately after harvest or just prior to shipping of cut flowers, flowering potted plants and foliage plants.
Comments	• Treatment period is dependent on storage temperature; minimum of 4 hours is required when done at 10–24°C and 8 hours when done between 2–10°C. • Treatment rooms must be posted, vents closed but with good internal air circulation and vented for 30 minutes prior to re-entry.

11. Pest and Disease Control in Greenhouses

This chapter consists of two tables, both of which list pesticide recommendations for greenhouse flower crops. Table 11-1. *Pesticide Recommendations – By Pesticide,* on this page, summarizes the registered pesticides and the pests and crops on which they can be used. The products in this table appear alphabetically by product name. However, when there is more than one product with the same active ingredient, they are grouped together, with the alphabetically correct product listed first.

Table 11-2. *Pesticide Recommendations – By Pest,* on page 116, is a detailed listing of pesticide recommendations for each pest or disease. For each pest, a list is provided of all registered control products and the recommended rates. **Note that the rates often include ranges and may be different depending on the crop. Always confirm uses and rates on the label before using.** In this table, the order of products does not represent any preference, although more recently registered products are usually listed nearer to the top. Also note that the Insecticide and Fungicide Group Numbers are provided next to the pesticide name. The relevance of these numbers is more fully explained in Chapter 9, *Pesticide Application, Toxicity and Activity,* on page 93, and Appendix F. *Pesticide Groups Based on Sites of Action,* on page 134. Repeating them in this table provides a quick reference for growers wishing to develop a pesticide rotation program.

All pesticides are evaluated by the Pest Management Regulatory Agency for efficacy and are now divided into 3 categories: "control" – efficacy ratings between 85–100%; "suppression" – efficacy between 65–85%; and "partial suppression" or "reduction in damage" – efficacy less than 65%. In the comments column of Table 11-2. *Pesticide Recommendations – By Pest,* on page 116, those products registered for suppression are noted. There are no products currently registered for use in greenhouse ornamentals for partial suppression. If the level of control is not mentioned, it can be assumed as "control" although it is important to remember that individual pest populations may show variations in the level of control achieved. Resistance, for example, may reduce efficacy of a particular product considerably.

Many pesticides can cause phytotoxic reactions under certain conditions. Read the label carefully and refer to the section in Chapter 9, *Pesticide Injury (Phytotoxicity) to Flower Crops,* on page 100.

Table 11–1. Pesticide Recommendations – By Pesticide

Insecticides		
Trade Name (active ingredient)	**Pests**	**Crops**
Avid (abamectin)	Spider mites, leafminers	Greenhouse ornamentals
Botanigard 22 WP, BotaniGard ES *(Beauveria bassiana)*	Aphids, whiteflies, thrips	Greenhouse ornamentals
Citation (cyromazine)	Leafminer, fungus gnats, shoreflies	Greenhouse ornamentals
Confirm (tebufenozide)	Armyworms, cutworms, cabbage loopers, tobacco budworm, leafrollers	Greenhouse ornamentals
Dibrom (naled)	Whiteflies, aphids, spider mites, leafrollers, mealybugs	Rose, cut flowers
Dimilin (diflubenzuron)	Fungus gnats, shoreflies	Greenhouse ornamentals
Dipel 2X DF, BioProtec 3P, Dipel WP, BioProtec CAF, Thuricide HPC (*Bacillus thuringiensis* kurstaki)	Leafrollers, cabbage looper, Duponchelia Leafrollers, cabbage looper	Greenhouse ornamentals as indicated on label
Distance (pyriproxifen)	Whiteflies	Greenhouse ornamentals
DDVP smoke fumigator (dichlorvos)	Aphids, spider mites, western flower thrips, whiteflies, mealybugs	Greenhouse ornamentals
DDVP 20% EC (dichlorvos)	Aphids, whiteflies	Greenhouse ornamentals

Table 11–1. Pesticide Recommendations – By Pesticide (con't)

Insecticides

Trade Name (active ingredient)	Pests	Crops
DeltaGard (deltamethrin)	Western flower thrips	Greenhouse floriculture crops (chrysanthemum, cineraria, Easter lily, geranium)
Dursban WSP, Dursban T, Pyrate 480 (chlorpyrifos)	Thrips, whiteflies, scale, mealybugs, leafhoppers	Greenhouse ornamentals
Dyno-Mite (pyridaben)	Whiteflies, spider mites	Greenhouse ornamentals
Endeavor (pymetrozine)	Aphid control, whitefly suppression	Greenhouse ornamentals
Enstar II (kinoprene)	Whiteflies, aphids	Greenhouse ornamentals
Floramite SC (bifenazate)	Two-spotted spider mite, Lewis mite	Greenhouse ornamentals
Forbid 240 SC (spiromesifen)	Mites, whiteflies	Greenhouse ornamentals
Insecticidal soaps	Aphids, whiteflies, spider mites, mealybugs, soft brown scale	Greenhouse ornamentals
Intercept 60 WP (imidacloprid)	Aphids, whiteflies	Greenhouse ornamentals
Kelthane 50W (dicofol)	Mites	Greenhouse ornamentals
Malathion 25W, Malathion 50, Malathion 500 E (malathion)	Aphids, whiteflies, thrips, mealybugs, spider mites	Chrysanthemum, carnation, rose, geranium, snapdragon
Nicotine Smoke Fumigator (nicotine)*	Aphids, thrips, rose midge, chrysanthemum midge	Greenhouse ornamentals
Orthene 75 SP (acephate)	Aphids, thrips, whitefly, rose midge, leafroller, scale	Greenhouse ornamentals as indicated on the label
Pounce 384 EC, Ambush 50 EC (permethrin)	Duponchelia (Pounce 384 only), whitefly, chrysanthemum leafminer	Greenhouse ornamentals as indicated on label
Shuttle 15 SC (acequinocyl)	Spider mites	Greenhouse ornamentals (other than cut flowers)
Success 480 SC (spinosad)	Western flower thrips	Greenhouse ornamentals
Thiodan 50WP, Thiodan 4EC; Thionex 50W, Thionex EC (endosulfan)	Aphids, whitefly, cyclamen mite	Greenhouse ornamentals
Tristar 70 WSP (acetamiprid)	Aphids, leafhoppers, whiteflies	Greenhouse ornamentals
Vectobac 600L (*Bacillus thuringiensis* israelensis)	Fungus gnats	Greenhouse ornamentals
Vendex 50W	Spider mites	Greenhouse ornamentals

* Nicotine registration is being phased out. Last date of sale by retailers is December 31, 2011 and last date of permitted use by growers is December 31, 2012.

Fungicides

Trade Name (active ingredient)	Diseases	Crops
Acrobat 50 WP (dimethomorph)	Downy mildew	Greenhouse ornamentals
Actinovate SP *(Streptomyces lydicus)*	Powdery mildew	Gerbera
Aliette T&O (fosetyl-Al)	*Pythium, Phytophthora*	Greenhouse ornamentals
Botran 75W (dicloran)	*Botrytis*	Rose, geranium, chrysanthemum
Compass 50 WG (trifloxystrobin)	*Rhizoctonia*, powdery mildew	Greenhouse ornamentals as indicated on label
Contans	*Sclerotinia*	Greenhouse ornamentals as indicated on label
Daconil 2787, Daconil Ultrex (chlorothalonil)	Various foliar diseases (see label)	Various bulb, flowering and foliage plants (see label)
Decree 50 WDG (fenhexamid)	*Botrytis*	Greenhouse ornamentals
Folpan 50 WP, 80 WDG (folpet)	*Pythium* root rot	Poinsettia
Maestro 80 DF, SupraCaptan 80 WDG (captan)	Damping-off, root rots, leaf spots (see label)	Greenhouse rose, other flowers

Table 11–1. Pesticide Recommendations – By Pesticide (con't)

Fungicides

Trade Name (active ingredient)	Diseases	Crops
Meltatox 40 EC (dodemorph acetate)	Powdery mildew	Rose
Milstop (potassium bicarbonate)	Powdery mildew	Various greenhouse ornamentals (see label)
Mycostop *(Streptomyces griseoviridis)*	*Fusarium, Pythium, Phytophthora*	Greenhouse ornamentals
No-Damp (oxine benzoate)**	Damping-off	Ornamental seedlings and cuttings
Nova 40 W (myclobutanil)	Rusts, powdery mildew	Geranium, poinsettia, rose, gerbera, aster, chrysanthemum
Phyton 27 (elemental copper)	Various fungal and bacterial foliar diseases (see label)	Various crops as foliar spray, cutting dip and postharvest application (see label)
PreStop *(Gliocladium catenulatum)*	*Pythium, Phytophthora, Rhizoctonia, Botrytis*	Greenhouse ornamentals as indicated on label
Previcur N (propamocarb hydrochloride)	*Pythium, Phytophthora*	Various greenhouse ornamentals (see label)
Quintozene 75 WP (quintozene)	*Rhizoctonia, Sclerotinia*	Various ornamental and bulb crops (see label)
Rhapsody ASO *(Bacillus subtilis)*	Powdery mildew, *Botrytis*, leaf spots,	Various greenhouse ornamentals (see label)
Rootshield Drench, RootShield Granules *(Trichoderma harzianum)*	Root diseases caused by *Rhizoctonia, Pythium* and *Fusarium*	Greenhouse ornamentals
Rovral 50 WP, Rovral WDG (iprodione)	*Botrytis*, damping-off *(Rhizoctonia)*	Ornamentals
Senator 70 WP (thiophanate-methyl)	*Rhizoctonia, Fusarium*, powdery mildew, *Botrytis*, leaf spots	Greenhouse potted ornamentals
Subdue Maxx, (metalaxyl)	*Pythium, Phytophthora*	Greenhouse ornamentals
Truban 30 WP, Truban 25 EC (etridiazole)	*Pythium, Phytophthora*	Various bedding, foliage, container and bed-grown ornamentals (see label)

**No-Damp has been discontinued by the registrant. Product in the possession of the grower may be used legally until December 31, 2011.

Other Pesticides

Trade Name (active ingredient)	Pest	Crops
Deadline M-Ps (metaldehyde)	Slugs	Ornamentals
Slug-Em (metaldehyde)	Slugs	Ornamentals
Sluggo (ferric phosphate)	Slugs	Outdoor and greenhouse ornamentals, nurseries

Table 11-2. Pesticide Recommendations – By Pest

Pest	Pesticide	IRAC Insecticide Group Number*	Rate/1,000 L (exceptions noted)	Crops/Comments
Insects/Mites				
Aphid (including tulip bulb aphid)	Intercept	4A	Read label carefully	• This product is for application as a drench on greenhouse ornamentals. Coconut growing medium may bind the active ingredient, making it unavailable to the plants.
	Tristar	4A	48 g (3 water soluble packs)	• This product is for use on greenhouse ornamentals as a foliar spray.
	Endeavor	9B	10–20 g/100 L	• This product is for use as a foliar spray on greenhouse ornamentals. Do not apply more than twice per crop cycle. Endeavor is compatible with many biocontrol agents.
	Enstar II	7A	25–75 mL/100 L	• This product is for use on greenhouse ornamentals.
	BotaniGard 22 WP BotaniGard ES	Biological	250–500 g/400 L 0.5–1.0 L/400L	• These products are biological insecticides for use on greenhouse ornamentals. BotaniGard is compatible with biocontrol programs.
	Insecticidal Soaps		20 L	• This product is for use on greenhouse ornamentals.
	Thiodan 4 EC Thiodan 50 WP Thionex EC Thionex 50 W	2A	1.25–1.75 L 1.0–1.5 kg 1.25–1.75 L 1.0 kg	• These products are for use on greenhouse ornamentals.
	DDVP Smoke Fumigator DDVP 20% EC	1B	1/300 m^3 6 L	• These products are for use on greenhouse ornamentals. When using the Smoke Fumigator, foliage must be dry.
	Malathion 25 W Malathion 50 Malathion 500 E	1B	2.5–5.0 kg 1.5 L	• These products are for use on greenhouse ornamentals.
	Nicotine Smoke Fumigator	4B	1/300 m^3	• This product is for use on greenhouse ornamentals. See footnote in Table 11-1 on page 114.
	Dibrom	1B	10 mL/100 m^3	• This product is for use on roses and cut flowers.
	Orthene 75 SP	1B	637 g	• This product is for use on greenhouse ornamentals as listed on the label.
Caterpillars (incl. leafrollers, cabbage looper, cutworm, armyworm, *Duponchelia*)	Confirm 240 F	18	1.0 L	• This product is for use on greenhouse ornamentals against armyworms, cutworms, corn earworm, grapevine moth, cabbage loopers, tobacco budworm and leafrollers.
	Dipel 2X DF	11	250 g/400 L	• This product is for use on roses against leafroller, chrysanthemum against cabbage looper and greenhouse ornamentals against *Duponchelia* larvae.
	Dipel WP		1.25 kg	• This product is for use on roses against leafroller and chrysanthemum against cabbage looper.
	Thuricide HPC		5 L	• This product is for use on roses against leafroller and chrysanthemum against cabbage looper.
	BioProtec CAF		1.8 L	• This product is for use on roses against leafroller and chrysanthemum against cabbage looper.
	BioProtec 3P		0.92 kg	• This product is for use on roses against leafroller, chrysanthemum against cabbage looper and greenhouse ornamentals against *Duponchelia* larvae.
	Orthene 75 SP	1B	850 g	• This product is for use on roses against leafroller and other labelled ornamental crops against armyworm and tobacco budworm.
	Dibrom	1B	10 mL/100 m^3 (vapour) 7–14 mL/100 m^2 (fog)	• This product is for use on roses and cut flower crops.
	Pounce 384 EC	3A	26 mL/100L	• This product is for use on labelled greenhouse ornamental crops against *Duponchelia* adults.

* See Appendix F. *Pesticide Groups Based on Sites of Action*, on page 134.

Table 11–2. Pesticide Recommendations – By Pest (con't)

Insects/Mites

Pest	Pesticide	IRAC Insecticide Group Number*	Rate/1,000 L (exceptions noted)	Crops/Comments
Cyclamen mite	Kelthane 50 W	3	525–700 g	• This product is for use on greenhouse ornamentals.
	Thiodan 4 EC Thiodan 50 WP Thionex EC Thionex 50 W	2A	1.25–1.75 L 1.0–1.5 kg 1.25–1.75 L 1.0 kg	• These products are for use on greenhouse ornamentals.
Fungus gnat	Citation 75 WP	17	133 g	• Apply as a drench to greenhouse ornamentals for larval control.
	Dimilin 25 WP	15	18–150 g	• This product is for use on greenhouse ornamentals except for Rieger begonia, hibiscus and poinsettia. Apply as a drench for larval control.
	Vectobac 600L	11	4–8 L	• Apply to greenhouse ornamentals as a drench for larval control.
Japanese beetle	Intercept 60 WP	4A	Read label carefully	• This product is for use on container-grown ornamentals requiring treatment prior to shipping as per CFIA Directive D-96-15.
	Dursban T Dursban Turf	1B	4.5 L	• These products are for use on container-grown ornamentals requiring treatment prior to shipping as per CFIA Directive D-96-15. Read label carefully.
Leafhopper	Tristar 70 WSP	4A	80 g (5 water soluble packs)	• This product is for use on greenhouse ornamentals.
	Orthene 75 SP	1B	637 g	• This product is for use on labelled greenhouse ornamentals.
	Malathion 50 EC	1B	1.5 L	• This product is for use on greenhouse ornamentals.
	Dursban WSP Dursban T Pyrate 480 SC	1B	0.896 kg (8 water soluble packs) 1.0 L 1.0 L	• These products are for use on greenhouse ornamentals.
Leafminer	Avid 1.9 EC	6	600 mL	• This product is for use on greenhouse ornamentals against leafminer larvae.
	Citation 75 WP	17	188 g	• This product is for use on greenhouse ornamentals against leafminer larvae.
	Pounce 384 EC Ambush 50 EC	3A	26 mL/100 L 20 mL/100 L	• These products are for use on labelled greenhouse ornamental crops.
Mealybug	DDVP Smoke Fumigator	1B	1/300 m³	• This product is for use on greenhouse ornamentals. Foliage must be dry.
	Malathion 25 W Malathion 50 EC	1B	2.5–5.0 kg 1.5 L	• These products are for use on greenhouse ornamentals.
	Dursban WSP Dursban T Pyrate 480 SC	1B	224 g (2 water soluble packs) 200 mL 200 mL	• These products are for use on greenhouse ornamentals.
Scale	Dursban WSP Dursban T Pyrate 480 SC	1B	1.792 kg (16 water soluble packs) 2.0 L 2.0 L	• These products are for use on greenhouse ornamentals.
	Insecticidal soaps		20 L	• This product is for use on greenhouse ornamentals.
	Orthene 75 SP	1B	637 g	• This product is for use on labelled greenhouse ornamentals.

* See Appendix F. *Pesticide Groups Based on Sites of Action*, on page 134.

Table 11–2. Pesticide Recommendations – By Pest (con't)

Insects/Mites

Pest	Pesticide	IRAC Insecticide Group Number*	Rate/1,000 L (exceptions noted)	Crops/Comments
Shorefly	Citation 75 WP	17	133 g	• Apply this product as a drench to greenhouse ornamentals for larval control.
	Dimilin 25 WP	15	18–150 g	• This product is for use on greenhouse ornamentals except for Rieger begonia, hibiscus and poinsettia. Apply as a drench for larval control.
Thrips	Success 480 SC	5	50 mL	• This product is for use on greenhouse ornamentals. Note that resistance to this product has been documented for western flower thrips.
	DDVP Smoke Fumigator	1B	1/300 m^3	• This product is for use on greenhouse ornamentals. Foliage must be dry.
	BotaniGard 22 WP BotaniGard ES	Biological	250–500 g/400 L 0.5–1.0 L/400L	• These products are biological insecticides for use on greenhouse ornamentals. They are compatible with biocontrol programs.
	Nicotine Smoke Fumigator	4B	1/300 m^3	• This product is for use on greenhouse ornamentals. Foliage must be dry. See footnote in Table 11-1 on page 114.
	Malathion 25 W Malathion 50 EC	1B	2.5–5.0 kg 1.5 L	• These products are for use on greenhouse ornamentals.
	Dursban WSP Dursban T Pyrate 480 SC	1B	448 g (4 water soluble packs) 500 mL 500 mL	• These products are for use on greenhouse ornamentals.
	DeltaGard SC	3A	0.35–0.5 L	• This product is for use on chrysanthemum, cineraria, Easter lily and geranium.
	Orthene 75 SP	1B	850 g	• This product is for use on greenhouse ornamentals as indicated on the label.
Two-spotted spider mite	Shuttle 15 SC	20B	0.21–0.46 L/500 L	• This product is for use on greenhouse crops other than cut flowers.
	Forbid 240 SC	23	30 mL/100 L	• This product is for use on greenhouse ornamentals. Read label carefully for crop safety information.
	Floramite SC	25	133 mL/400 L	• This product is for use on greenhouse ornamentals.
	Avid 1.9 EC	6	300 mL	• This product is for use on greenhouse ornamentals.
	Dyno-Mite 75 W	21A	142–284 g (5–10 PVA bags)	• This product is for use on greenhouse ornamentals.
	Vendex 50 W	12B	50–100 g/100 L	• Do not spray when plants are under stress (e.g. new transplants) or when temperature is >32°C.
	DDVP Smoke Fumigator	1B	1/300 m^3	• This product is for use on greenhouse ornamentals. Foliage must be dry.
	Kelthane 50 W	3	525–700 g	• This product is for use on greenhouse ornamentals.
	Insecticidal soaps		20 L	• This product is for use on greenhouse ornamentals.
	Malathion 25 W Malathion 50 EC	1B	2.5–5.0 kg 1.5 L	• These products are for use on greenhouse ornamentals.
	Orthene 75 SP	1B	637 g	• This product is for use on greenhouse ornamentals as indicated on the label.
	Dibrom	1B	10 mL/100 m^3	• This product is for use on roses and cut flowers.

* See Appendix F. *Pesticide Groups Based on Sites of Action*, on page 134.

Table 11–2. Pesticide Recommendations – By Pest (con't)

Insects/Mites

Pest	**Pesticide**	**IRAC Insecticide Group Number***	**Rate/1,000 L (exceptions noted)**	**Crops/Comments**
Whitefly	Distance	7C	45 mL/100 L	• This product is for use on greenhouse ornamentals.
	Forbid	23	30 mL/100L	• This product is for use on greenhouse ornamentals. Read label carefully for crop safety information.
	Intercept	4A	Read label carefully	• This product is for application as a drench on greenhouse ornamentals. Coconut growing medium may bind the active ingredient, making it unavailable to the plants.
	Tristar	4A	80–160 g (5–10 water soluble packs)	• This product is for use on greenhouse ornamentals.
	Dyno-Mite 75 W	21A	284–425 g (10–15 PVA bags)	• This products is for use on greenhouse ornamentals.
	Enstar II	7A	25–75 mL/100 L	• This product is for use on greenhouse ornamentals.
	BotaniGard 22 WP BotaniGard ES	Biological	250–500 g/400 L 0.5–1.0 L/400L	• These products are biological insecticides for use on greenhouse ornamentals. They are compatible with biocontrol programs.
	Insecticidal Soaps		20 L	• This product is for use on greenhouse ornamentals.
	Endeavor	9B	10–20 g/ 100 L	• This product is for use on greenhouse ornamentals. It provides suppression of whitefly.
	Thiodan 4 EC Thiodan 50 WP Thionex EC Thionex 50 W	2A	1.25–1.75 L 1.0–1.5 kg 1.25–1.75 L 1.0 kg	• These products are for use on greenhouse ornamentals.
	DDVP Smoke Fumigator DDVP 20% EC	1B	1/300 m^3 6 L	• These products are for use on greenhouse ornamentals. When using the Smoke Fumigator, foliage must be dry.
	Dursban WSP Dursban T Pyrate 480 SC	1B	448 g (4 water soluble packs) 500 mL 500 mL	• These products are for use on greenhouse ornamentals.
	Malathion 25 W Malathion 50 EC	1B	2.5–5.0 kg 1.5 L	• These products are for use on greenhouse ornamentals.
	Pounce 384 EC Ambush 50 EC	3A	26 mL/100 L 20 mL/100 L	• These products are for use on labelled greenhouse ornamental crops.

* See Appendix F. *Pesticide Groups Based on Sites of Action*, on page 134.

Table 11–2. Pesticide Recommendations – By Pest (con't)

Diseases				
Disease	**Pesticide**	**FRAC Fungicide Group Number***	**Rate/1,000 L (exceptions noted)**	**Crops Comments**
Botrytis	Decree 50 WDG	17	1.12 kg	• This product is for use on greenhouse ornamentals using high volume or low volume equipment at 1.12 kg/ha.
	Daconil 2787 Daconil Ultrex	M5	2.5 L 1.5 kg	• This product is for use on various bulb, flowering and foliage plants as listed on the label.
	Rovral 50 WP	2	1.0 kg	• This product is for use on greenhouse ornamentals.
	Botran 75 WP	14	925 g 1.75 kg	• Apply this rate as a foliar spray to rose, geranium, and chrysanthemum. • This rate is for use on rose and hydrangea. Apply prior to lifting for shipment or storage; spray or dip stored plants.
	Senator 70 WP	1	650–850 g	• This product is for use on greenhouse potted ornamentals.
	PreStop	NC	100–200 g/20 L	• Mix and apply according to the label for use on greenhouse ornamental plants. This product provides disease suppression.
	Maestro 80 DF Supra-Captan 80 WDG	M4	1.2–1.5 kg 1.2–1.5 kg	• These products are for use on ornamental crops as listed on the label. Read the label carefully.
	Rhapsody ASO	44	1–2 L/100 L	• This product is for disease suppression on greenhouse ornamentals as listed on the label.
	Phyton 27	M1	100–250 mL/100 L (foliar spray) 0.2–1.0 mL/L (cut flower dip)	• This rate is for use on greenhouse ornamentals as listed on the label. • This rate is for use as a post-harvest cut flower dip (see label).
Downy mildew	Acrobat 50 WP	40	48 g/100 L	• This product is for use on greenhouse ornamentals. Do not use on greenhouse cut flowers.
Fusarium	Senator 70 WP	1	650–850 g	• This product is for use on greenhouse potted ornamentals.
	Mycostop	NC	Read label carefully for rates	• This product is for suppression of *Fusarium* on greenhouse ornamentals as a seed treatment, drench or spray. Follow label instructions carefully.
	RootShield	NC	30–45 g/100L	• Apply to potting mix or as a drench to greenhouse ornamentals for disease suppression.
Leaf spots (including *Alternaria*, Athracnose, *Ascochyta* ray blight, Cercospora, Septoria, black spot of rose)	Maestro 80 DF Supra Captan 80 WDG	M4	1.2–1.5 kg 1.2–1.5 kg	• Read label carefully for listed crops and diseases.
	Daconil 2787 Daconil Ultrex	M5	2.5 L 1.5 kg	• Read label carefully for listed crops and diseases.
	Senator 70 WP	1	500–850 g	• Read label carefully for rates on different crops.
	Rhapsody ASO	44	1.0–2.0 L	• This product is for use on listed crops and diseases. Read label carefully.
	Folpan 80 WDG	M4	1.25 kg	• This product is for listed leaf spots on carnation, marigold, zinnia, chrysanthemum, iris and snapdragon.

*See Appendix F. *Pesticide Groups Based on Sites of Action*, on page 134.
NC – Not classified

Table 11–2. Pesticide Recommendations – By Pest (con't)

Diseases				
Disease	**Pesticide**	**FRAC Fungicide Group Number***	**Rate/1,000 L (exceptions noted)**	**Crops Comments**
Powdery mildew	Nova 40 W	3	340 g	• Apply to greenhouse ornamentals as listed on the label.
	Phyton 27	M1	125–250 mL/100 L	• This product is for use on greenhouse ornamentals as listed on the label.
	Actinovate SP	NC	170 g/380 L	• Apply at transplant for suppression of powdery mildew in gerbera daisy. Read the label carefully.
	Milstop	NC	2.8–5.6 kg/ha	• Use this product for control/suppression of powdery mildew in greenhouse grown ornamentals and for suppression in bedding plants grown outdoors.
	Rhapsody ASO	44	1–2 L/100L	• This product is for suppression of powdery mildew on greenhouse ornamentals as listed on the label.
	Senator	1	500–850 g	• Read label carefully for rates on different crops.
	Meltatox 40 EC	5	2.5 L	• This product is for use on roses only.
Root and crown rots *Pythium/ Phytophthora*	Previcur N	28	1.5 mL/L	• For *Pythium,* apply as a drench to greenhouse ornamentals at a rate of 100 mL/10 cm pot. • For *Phytophthora,* apply 4.9 L mixed solution/m^2. • Apply so that the foliage does not get wet.
	Subdue Maxx	4	5 mL/m^3 24–40 mL	• Incorporate this rate with growing medium at seeding and transplanting. • Apply this rate as a drench to bedding plants as listed on the label. The high rate is for use on gloxinia, but may cause phytotoxicity.
	Truban 25 EC	14	90–115 mL/380 L 115–240 mL	• This rate is for use as a drench on bedding plants at 380 L/75 m^2. • Apply this rate as a drench to foliage plants and potted plants as listed on the label.
	Truban 30 WP		150–225 g/600 L 225–900 g/1200L 55–110 g/m^3	• Apply this rate as a drench to bedding plants. • Apply this rate as a drench to foliage plants and potted plants as listed on the label. • Incorporate this rate with dry growing medium.
	Aliette T&O	33	2.8 kg 360 g/380 L	• This rate is for foliar application on greenhouse ornamentals. • This rate is for drench applications on bedding plants. • Has excellent activity against *Phytophthora.*
	RootShield Drench	NC	30–45 g/100 L	• Apply this rate to potting mix or as a drench to greenhouse ornamentals for suppression of *Pythium.*
	RootShield Granules		600–750 g/m^3	• Incorporate this rate with the growing medium for suppression of *Pythium* in greenhouse ornamentals. Read the label carefully.
	PreStop	NC	100–200 g/20 L	• For suppression of *Pythium,* apply according to instructions as a growing medium mix or as a drench. Follow label instructions carefully.
	Mycostop Biofungicide	NC	Read label carefully for rates	• This product is for suppression of *Pythium* and *Phytophthora* on greenhouse ornamentals as a seed treatment, drench or spray. Follow label instructions carefully.
	Folpan 50 WP Folpan 80 WDG	M4	2.0–2.25 kg 1.25–1.4 kg	• Apply at planting for control of *Pythium* in poinsettias.

*See Appendix F. *Pesticide Groups Based on Sites of Action,* on page 134.
NC – Not classified

Table 11–2. Pesticide Recommendations – By Pest (con't)

Disease	Pesticide	FRAC Fungicide Group Number*	Rate/1,000 L (exceptions noted)	Crops Comments
Diseases				
Root and stem rot *Rhizoctonia*	Compass 50 WG	11	3.8 g/100 L	• Apply this product as a drench to greenhouse ornamentals at seeding, rooting or transplanting for control of *Rhizoctonia*.
	Quintozene	14	1.0–1.25 kg/100 m^2 1 kg/10 L	• This rate is for use on labelled ornamental crops. Incorporate this rate into the top 5 cm of soil or apply as a drench. • Apply this rate as a bulb dip.
	Senator 70 WP	1	650–850 g	• Apply this product to greenhouse potted ornamentals as a drench or directed spray to the growing medium.
	Maestro 80 DF, Supra-Captan 80WDG	M4	3–6 g/L 1.25 kg 3.75–9.5 kg	• Apply this rate as a cutting dip to labelled crops. • Apply this rate as a drench to soil beds. • Apply this rate as a bulb dip to labelled crops.
	PreStop	NC	100–200 g/20 L	• Apply this product according to instructions as a growing medium mix or as a drench. For suppression of *Rhizoctonia*. Follow label instructions carefully.
	RootShield Drench	NC	30–45 g/100 L 60 g/L (bulb dip)	• Apply this rate to potting mix or as a drench to greenhouse ornamentals for suppression of *Rhizoctonia*. • Use this rate as a bulb dip.
	RootShield Granules		600–750 g/m^3	• Incorporate this rate with the growing medium for suppression of *Rhizoctonia* in greenhouse ornamentals. • Read the label carefully.
	No-Damp	M2	10 L	• This product is for use on greenhouse ornamentals to control damping off. See footnote in Table 11-1 on page 115.
Rust	Nova 40 W	3	250–540 g	• This product is for use on listed ornamental crops. Read label carefully for rates on different crops.
	Daconil 2787 Daconil Ultrex	M5	2.5 kg 1.5 kg	• These products are for use on listed ornamental crops.
Erwinia	Phyton 27	M1	150–250 mL/100 L	• This product is for use as a cutting dip on poinsettia.

*See Appendix F. *Pesticide Groups Based on Sites of Action*, on page 134.
NC – Not classified

12. Pest Control Products for Outdoor Herbaceous Ornamentals

Integrated Pest Management (IPM) in Outdoor Ornamentals (Including Field-Grown Cut Flowers, Perennials and Potted Plants)

IPM in outdoor ornamental and flower crops involves the same principles used in greenhouse production. However, there are some differences.

Monitoring is still the cornerstone of an IPM program, but there may be less reliance on the use of yellow sticky cards as an insect-monitoring tool due to wind-blown dust and debris collecting on them and limiting their usefulness. Regularly inspect crops to detect problems early. As with greenhouse-grown crops, there are large variations in the susceptibility of crops and varieties to diseases and insects. Knowing this can greatly increase the efficiency of crop inspections, by targeting first those crops that are most likely to have pests or diseases.

In outdoor production, there is no control over the weather. Cool, damp conditions will increase the likelihood of disease outbreaks. Strong winds may result in sudden and unexpected outbreaks of insect pests that have been blown in from elsewhere. However, the outside environment will never be as perfect for pest development as it is in a greenhouse. Variability in weather such as cool or cold nights and rain can slow the development of pests compared to a similar situation in the greenhouse.

Biological control may not offer the same options for control as it does in the enclosed environment of greenhouses. For example, flying insects such as parasitic wasps are not constrained to stay in the crop. Predatory mites (which do not fly) may be useful, but there has been little experience with them in these situations.

The use of pesticides outdoors also requires different thinking. Products registered for greenhouse use are not necessarily registered for outdoor ornamentals. For more information, see Table 12-1. *Insecticides/Miticides Registered for Use on Outdoor Ornamental Crops in Canada,* on page 124, Table 12-2. *Fungicides Registered for Use on Outdoor Ornamental Crops in Canada,* on page 124, and Table 12-3. *Other Pesticides Registered for Use on Outdoor Ornamental Crops in Canada,* on page 125. Be aware of the potential for drift into non-target areas, proximity to watercourses and ponds, and the impact on non-target organisms such as honeybees.

Integrated Weed Management in Outdoor Flower Production

The other major difference between greenhouse and outdoor production of flowers and other ornamental crops is in the need for weed management. Herbicides have a much more important role in outdoor flower production than in greenhouse production.

A successful weed management program must integrate cultural and chemical weed control practices. Growers cannot depend entirely on chemical weed control in outdoor flower crops, since there is a limited spectrum of herbicides registered for these crops. There are many ways of reducing weed problems:

- Choose a low weed-pressure site:
  - **Select fields with lower weed pressure.** Problem weeds, for example annuals such as pigweed, ragweed and lamb's quarters, as well as perennials, make weed control programs more difficult. Use a five-year plan to reduce weeds in your next plantings.
  - **Grow rotational crops that reduce weeds.** For example, winter wheat in the previous year breaks the life cycle of annual weeds and allows the use of hormone herbicides (e.g. 2,4-D) to control broadleaf weeds.
  - **Grow crops with a wider choice in herbicides.** For example, corn reduces weed populations before planting flowers. Avoid persistent herbicides that may harm flower crops in future plantings.

Table 12–1. Insecticides/Miticides Registered for Use on Outdoor Ornamental Crops in Canada

Insecticides	Pests	Crops
Apollo (clofentezine)	Two-spotted spider mite	Outdoor deciduous nursery stock
Cygon 480, Lagon 480 (dimethoate)	Various insect pests (see label)	Outdoor ornamentals (see label)
*Diazinon 500 E, Diazol 50 W, Diazol 50 EC, Diazinon 50 W, Diazinon 500 EC (diazinon)	Various insect pests (see label)	Various ornamentals (see label)
Dibrom (naled)	Aphids, leafhoppers, spider mites, other listed pests (see label)	Outdoor ornamentals (see label)
Dipel WP, Dipel 2DF, BioProtec CAF *(Bacillus thuringiensis* kurstaki)	Listed caterpillars	Ornamental and shade trees
Dursban WSP, Dursban T, Pyrate 480 EC, Dursban Turf (chlorpyrifos)	Various insect pests (see label)	Outdoor ornamental plants
Dyno-Mite (pyridaben)	Various mite pests (see label)	Outdoor ornamental plants
Endeavor 50 WG (pymetrozine)	Aphids	Outdoor ornamental plants
Forbid 240 EC (spiromesifen)	Two-spotted spider mites, broad mites, whitefly	Outdoor ornamental plants
Imidan 50 WP (phosmet)	Elm spanworm, gypsy moth, Japanese beetle	Outdoor herbaceous plants (see label)
Insecticidal soap (potassium salts of fatty acids)	Various insect and mite pests (see label)	Outdoor flowers, ornamentals (see label)
Intercept 60 WP (imidacloprid)	European chafer, Japanese beetle	Outdoor ornamental crops
Kelthane 50 W (dicofol)	Mites	Outdoor ornamentals
Landscape oil (mineral oil)	Various insect and mite pests	Labelled ornamental crops
Malathion 50, Malathion 25W, Malathion 50 E (malathion)	Various insect and mite pests (see label)	Ornamental plants; trees, shrubs and flowers
Met52 (Metarhizium anisopliae, Strain F52)	Black vine weevil, strawberry root weevil	Container grown ornamentals
Orthene (acephate)	Aphids, caterpillars, lacebugs, leafhoppers, psyllids, rose midge, thrips, whitefly, mealybugs, scale, spider mites	Outdoor flowers, ornamentals, shrubs, trees, rose
Sevin (carbaryl)	Various insect pests (see label)	Various outdoor ornamentals (see label)
Shuttle 15 SC (acequinocyl)	Spider mites	Outdoor ornamentals
Success 480 SC (spinosad)	Thrips and other pests (see label)	Outdoor ornamentals
Thiodan 50 WP, Thiodan 4 EC, Endosulfan 50 W, Endosulfan 400 E, Thionex EC (endosulfan)	Various insect and mite pests (see label)	Outdoor ornamentals
Tristar 70 WSP (acetamiprid)	Various insect pests (see label)	Ornamental and flowering plants

* The PMRA is requiring the phase out of diazinon uses in outdoor ornamentals (Re-evaluation Decision, RVD2009-18). For these uses, Diazinon will continue to be sold until March 2012. Contact the OMAFRA Floriculture Specialists for more information.

Table 12–2. Fungicides Registered for Use on Outdoor Ornamental Crops in Canada

Fungicides	Diseases	Crops
Acrobat 50 WP	Downy mildew (control), *Phytophthora ramorum* (suppression)	Outdoor grown ornamental crops
Aliette (fosetyl-Al)	Sudden Oak Death *(Phytophthora ramorum)*	For disease suppression
Banner Maxx (propiconazole)	Various diseases (see label)	Outdoor ornamental crops (see label)
Botran 75 W (dicloran)	*Botrytis*	Rose, hydrangea (outdoors)
Compass 50 WG (trifloxystrobin)	Powdery mildew, scab, Rhizoctonia	Various outdoor ornamentals (see label)
Daconil 2787, Daconil Ultrex (chlorothalonil)	Various diseases (see label)	Various outdoor ornamental crops (see label)
Decree 50 WDG (fenhexamid)	*Botrytis*	Outdoor ornamentals
Dithane DG (mancozeb)	Various foliar diseases (see label)	Woody ornamentals (see label)
Folpan 50 WP, Folpan 80 WDG (folpet)	Various foliar diseases, root and stem rot (see label)	Various outdoor ornamentals (see label)

Table 12–2. Fungicides Registered for Use on Outdoor Ornamental Crops in Canada (con't)

Fungicides	Diseases	Crops
Funginex 190 EC (triforine)	Black spot of roses, powdery mildew	Outdoor ornamentals
Heritage (azoxystrobin)	Daylily rust	Daylilies
Maestro 80 DF, Captan 80WDG, Captan 50 W (captan)	Foliar diseases, damping-off, bulb rot (see label)	Outdoor ornamentals listed (see label)
Milstop (potassium bicarbonate)	Powdery mildew	Provides disease suppression on outdoor ornamental crops.
Nova 40 W (myclobutanil)	Rusts, powdery mildew, leaf spots (see label)	Various outdoor ornamentals (see label)
Previcur N (propamocarb hydrochloride)	*Pythium, Phytophthora*	Various outdoor ornamentals (see label)
Rhapsody ASO *(Bacillus subtilis)*	Suppression of powdery mildew, *Botrytis*, leaf spots, *Rhizoctonia, Pythium, Phytophthora*	Various outdoor ornamentals (see label)
RootShield *(Trichoderma harzianum)*	Suppression of *Botrytis* and root diseases	Outdoor ornamental crops
Rovral, Rovral WDG (iprodione)	*Botrytis, Rhizoctonia*	Outdoor ornamentals (see label)
Senator 70 WP (thiophanate-methyl)	Black spot of roses, powdery mildew	Outdoor ornamentals
Subdue Maxx (metalaxyl)	*Pythium, Phytophthora* Suppression of *Phytophthora ramorum*	Outdoor ornamentals

Table 12–3. Other Pesticides Registered for Use on Outdoor Ornamental Crops in Canada

Pesticide	Pest	Crops
Deadline M-Ps (metaldehyde)	Slugs	Ornamentals
SlugEm (metaldehyde)	Slugs	Nurseries
Sluggo (ferric phosphate)	Slugs	Outdoor ornamentals, nurseries

- Prepare the site:
  - **Identify weeds.** Watch for these weeds common in outdoor flower production: perennial weeds like quackgrass, bindweed, vetch, wild grape, perennial nightshade, thistles, ground-ivy (creeping charlie), willowherb and burdock; biennials like dandelions, wild carrot and biennial wormwood. Winter annuals like sow thistles, fleabanes, mustards, peppergrass, shepherd's purse and flixweed can also be a challenge because they establish through the fall.
  - **Eradicate perennial and biennial weeds.** It is important to identify and control these tough weeds in the preplanting year, because they are very difficult to control after planting. Apply systemic herbicides such as glyphosate (e.g. Roundup) to perennial weeds in the preplanting year. Use the recommended rate for each weed (note the higher rates recommended on labels for perennial weeds), and apply it when the weed reaches the sensitive stage of growth. Use a sprayer designated solely for applying glyphosate to reduce the risk of damaging crops. Repeated cultivations of some perennial weeds (e.g. bindweed) will also provide control, but avoid dragging weeds to clean areas of the field.
  - **Grow a green manure crop.** Cover crops like cereals, perennial ryegrass, pearl millet or Sudan-sorghum grown in the preplanting year will both compete with weeds and improve soil structure. There are several key times to use herbicides in these crops to reduce weeds: before planting (non-selective herbicides e.g. glyphosate or Gramoxone), shortly after establishment of the green manure crop (short residual herbicides, e.g. 2,4-D, bromoxynil, dicamba), and before plowdown. Avoid using herbicides that leave a soil residue to carry over into the planting year (e.g. Atrazine, simazine, Karmex).
- Avoid weeds in production years:
  - **Set up a stale seedbed.** This technique is useful for crops seeded or planted later in the spring. Cultivate the area as early as possible (April or early May) to encourage germination of weeds. Just before planting time, kill emerged weeds with

herbicides (e.g. glyphosate, Gramoxone), flamers or steam. Plant directly into undisturbed soil to avoid bringing new weed seeds to the surface. For seeded crops, the burndown can be repeated if necessary (very carefully) just before the crop emerges. A plate of glass set on freshly worked ground will encourage weed seed germination and will signal when to apply this second burndown safely before the crop emerges.

- **Manage weeds in row middles.** Cultivation can control weeds between the rows but will decrease soil organic matter. Alternatively, planting grass strips between the rows will prevent weeds from becoming established. Choose a grass mixture of low-maintenance grasses that tolerate drought, like creeping red fescue or perennial ryegrass. Timely mowing can prevent weeds from seeding into crops. Use of sod row middles increases the need for irrigation and/or nitrogen fertilizer.

- **Prevent weed seeds.** Control weeds in field edges and adjacent areas before they set seed. Try to control weed escapes in crops before they set seed, by cultural removal or chemical mowing. Mowing at regular intervals will prevent many weeds from flowering. Watch for weeds that sprout low branches that may flower lower than mower blades and manually remove them.

- Use many weed-control tools:

  - **Cultivation.** Generally, cultivating when weeds are small and soils are drying is most effective. Different cultivation tools work at different timings for different weeds. Rotary hoes, tine cultivators, rolling baskets, rotating disks, brushes and interplant cultivators may be effective in flower crops. Frequent hand hoeing when weeds are tiny can be quick and effective.

  - **Hilling.** Row crops like gladiolus benefit from regular hilling which provides support for the plant and weed control. Equipment is available that can move soil toward the plants on one pass and pull it away on the next if a mound is not desirable.

  - **Mowing.** Small mowers can manoeuvre around many plants to mow weeds. This can be very effective to prevent weed flowers and seeds, but mowing does not eliminate weed competition for moisture. Weed whips are very useful for selective cutting, both with a blade and a string attachment. Removal of flower heads from the area may be needed to avoid seed shed after mowing.

  - **Flamers.** Equipment that directs a hot propane flame to kill weeds can be very effective. Driving speeds of 5–10 km/h are required to avoid damage to the crop, so fields need to be designed with straight rows and large turning areas. Hand-held flamers are also available but quick movement of the flame is still important.

  - **Mulching.** A thick layer of mulch can prevent weed germination and conserve soil moisture. Apply weed-free mulch after planting but before weeds emerge. Use plastic mulch under short-term crops, and planters to plant through the plastic. Dark plastic gives the best weed control, although other colours may have other uses. Biodegradable plastics avoid the problem of disposal after use. Organic mulch materials, e.g. straw or fine wood chips, can work well but be sure to provide enough nitrogen for the plants as they decompose. In the late fall, pull the mulch away from the base of the plants to discourage rodents over winter. Nursery ground-cover fabric can be especially useful for weed control in outdoor potted plant production and for perennial flowers that grow in clumps. This fabric is long lasting, provides drainage and is not as slippery as plastic. It provides a weed-free area, is durable and easy to keep clean. Weeds will establish on the edges of all mulches, so regular edge weeding is necessary.

  - **Herbicides.** Table 12-4. *Herbicides Registered for Use on Outdoor Ornamental Crops in Canada,* on page 127, lists a selection of herbicides registered for use on outdoor ornamental crops in Canada. Select a herbicide registered for use on the crop and apply it as directed on the label. Keep a separate, clearly-marked sprayer for herbicides and wash it out properly between uses with a tank cleaner like Agral 90. Sprayers with shrouds can prevent herbicides from contacting the crop, and other drift-reducing technologies like air-induction nozzles may be useful. Wick wiper applicators (either hand-held, tractor or ATV-mounted) can control weeds by wiping concentrated herbicides such as glyphosate directly on weeds. Selective drip applicators are also

Table 12–4. Herbicides Registered for Use on Outdoor Ornamental Crops in Canada

Herbicides	Weeds	Crops	Herbicide Group	Comments
Basamid Granular (fumigant) (dazomet)	PRE Germinating weed seeds	Outdoor flowers, ornamentals	27	· apply to weed-free soil · do not use below 6°C · open soil 5–7 days after treatment
Bonanza 400 Treflan EC Rival 500 EC (trifluralin)	PPI Annual grasses and broadleaf weeds (see label)	Perennials and woody ornamentals (see label)	3	· incorporate shallowly in two directions within 24 hours of application · place roots of transplants below treated layer
Casoron Granular Herbicide (dichlobenil)	Annual grasses, broadleaf weeds and certain perennial weeds	Outdoor ornamentals crops (see label)	20	· controls broad-leaved and grassy weeds at germination and weed growth initiation · apply when temperature is <15°C
Dacthal W75 (chlorthal dimethyl)	PRE Various including lamb's quarters, crabgrass, lovegrass, carpetweed, witchgrass, purslane, foxtail, common chickweed (see label)	Outdoor ornamentals (see label)	3	· apply to weed-free soil · irrigate or shallowly incorporate within 3–5 days if no rain falls
Devrinol 50 DF Devrinol 2 G Devrinol 10 G (napropamide)	PRE Weed control (see label)	Outdoor flowers, ornamentals (see label)	15	· apply to weed-free soil · requires 1 cm of rainfall or irrigation within 7 days (spring or fall) or 2 days (summer) to prevent breakdown by sunlight · very safe on plants
Dual Magnum (s-metolachlor)	PRE or early POST Nightshade, annual grasses and redroot pigweed	Outdoor ornamentals (see label)	15	· apply only once per year · use a minimum of 150–200 L water/ha
Gallery 75 DF (isoxaben)	PRE Broadleaf weeds	Containerized ornamentals (see label)	21	· apply late summer to early fall, early spring, any time prior to germination or immediately after cultivation · do not apply more than once per season
Kerb 50 WSP (propyzamide)	PRE Quackgrass, annual grasses, chickweed (see label)	Iris, peony, ground covers (see label)	15	· apply to weed-free soil · best in cool, moist soil
Roundup (glyphosate)	POST Broad spectrum weed control (see label)	Prior to planting on all crops	9	· systemic, avoid valuable plants · apply to actively growing plants at susceptible stages
Princep Nine-T Simadex, Simazine 480 (simazine)	PRE Various broadleaf weeds and annual grasses	Woody ornamentals and nursery stock (see label)	5	· apply to weed-free soil · repeated applications may leave soil residues that damage subsequent crops · use lower rate on low organic matter soils
Venture L (fluazifop)	POST Grass weeds (see label)	Outdoor ornamentals (see label)	1	· apply to actively growing grasses · do not cultivate for 5 days · test on a few plants for tolerance

PPI — preplant incorporated; PRE — preemergent; POST— postemergent (to the weeds)

available for very finely targeted applications next to flowers. Spot treatments can be very effective at controlling small patches of new weeds. For best results with glyphosate, wait until the flowering stage of perennial weeds like thistle or milkweed. Check equipment for drips and leaks before treating weeds to avoid dripping herbicide on the crop.

Note: Rotation of herbicide families (see Herbicide Groups in Table 12–4. *Herbicides Registered for Use on Outdoor Ornamental Crops in Canada,* on this page) is important to minimize the building up of seed from weed escapes, including triazine-tolerant weeds. Do not use herbicides from the same group year after year but switch between different group numbers. Rotation will also help avoid an accumulation of herbicide residues in the soil that may result in crop injury over a period of years and may harm subsequent crops.

13. Appendices

Appendix A. Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Floriculture Advisory Staff

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A complete list of Ontario Ministry of Agriculture, Food and Rural Affairs advisory staff is available on the ministry website at *www.ontario.ca/crops*.

Agricultural Information Contact Centre
Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.
1 Stone Rd. W.
Guelph, ON N1G 4Y2
Tel: 519-826-4047
Toll-free: 1-877-424-1300
Fax: 519-826-7610
Email: ag.info.omafra@ontario.ca

Appendix B. Ontario Ministry of Environment – Regional Offices Contact Information

REGION County	**Address**	**Telephone/Fax**
Central Region Toronto, Halton, Peel York, Durham	5775 Yonge St., 8th Floor Toronto, ON M2M 4J1	Tel: 416-326-6700 Toll-free: 1-800-810-8048 Fax: 416-325-2459
West-Central Region Haldimand-Norfolk, Niagara, Hamilton-Wentworth, Dufferin, Wellington, Waterloo, Brant	Ontario Government Building 119 King St. W., 12th Floor Hamilton, ON L8P 4Y7	Tel: 905-521-7640 Toll-free: 1-800-668-4557 Fax: 905-521-7820
Eastern Region Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/ Dundas & Glengarry, Haliburton, Peterborough, Victoria, Northumberland, Renfrew, Ottawa-Carleton, Lanark, (Townships of Airy, Murchison, Dickens, Lyell and Sabine)	P.O. Box 22032 1259 Gardiners Rd., Unit 3 Kingston, ON K7M 8S5	Tel: 613-549-4000 Toll-free: 1-800-267-0974 Fax: 613-548-6908
Southwestern Region Elgin, Middlesex, Oxford, Essex, Kent, Lambton, Bruce, Grey, Huron, Perth, Simcoe	733 Exeter Rd., 2nd Floor London, ON N6E 1L3	Tel: 519-873-5000 Toll-free: 1-800-265-7672 Fax: 519-873-5020
Northern Region	Thunder Bay Regional and District Office 435 James St. S., Suite 331 Thunder Bay, ON P7E 6S7	Tel: 807-475-1205 Toll-free: 1-800-875-7772 Fax: 807-475-1754
	Sudbury District Office 199 Larch St., Suite 1201 Sudbury, ON P3E 5P9	Tel: 705-564-3237 Toll-free: 1-800-890-8516 Fax: 705-564-4180
	Timmins District Office Ontario Government Complex P.O. Bag 3080 Hwy 101 East South Porcupine, ON P0N 1H0	Tel: 705-235-1500 Toll-free: 1-800-380-6615 Fax: 705-235-1520
Standards Development Branch	Pesticides Section 40 St. Clair Ave. W., 7th Floor Toronto, ON M4V 1M2	Tel: 416-327-5519 Fax: 416-327-2936
Approvals Branch	Pesticides Licensing 2 St. Clair Ave. W., 12A Floor Toronto, ON M4V 1L5	Tel: 416-314-8001 Toll-free: 1-800-461-6290 Fax: 416-314-8452

Appendix C. Greenhouse Media, Nutrient Solutions and Tissue Testing Laboratories in Ontario

Contact the individual laboratory for a listing of greenhouse-related analytical tests available.

Company	Address	Contact Details	Contact
Agri-Food Laboratories	503 Imperial Rd., Unit #1 Guelph, ON N1H 6T9	Tel: 519-837-1600 Toll-free: 1-800-265-7175 Fax: 519-837-1242 Website: *www.agtest.com* Email: lab@agtest.com	Trish Kelly Jack Legg
Stratford Agri Analysis Inc.	P.O. Box 760 1131 Erie St. Stratford, ON N5A 6W1	Tel: 519-273-4411 Toll-free: 1-800-323-9089 Fax: 519-273-4411 Website: *www.stratfordagri.ca* Email: saa@dacolabs.com	Keith Lemp Don MacPhail
A & L Canada Laboratories East	2136 Jetstream Rd. London, ON N5V 3P5	Tel: 519-457-2575 Fax: 519-457-2664 Website: *www.alcanada.com* Email: aginfo@alcanada.com	Ian McLachlin Greg Patterson
Exova Accutest Laboratories	146 Colonnade Rd., Unit #8 Nepean, ON K2E 7Y1	Tel: 613-727-5692 Fax: 613-727-5222 Website: *www.exova.ca* Email: firstname.lastname@exova.com	Rob Walker Lorna Wilson
Forest Resources and Soils Testing Laboratory	955 Oliver Rd., BB1005D Thunder Bay, ON P7B 5E1	Tel: 807-343-8639 Fax: 807-343-8116 Website: *http://lucas.lakeheadu.ca/forest/* Email: soilslab@lakeheadu.ca	Claire Riddell Joel Symonds
Soil and Nutrient Lab	University of Guelph, P.O. Box 3650 95 Stone Rd. W. Guelph, ON N1H 8J7	Tel: 519-767-6226 Fax: 519-767-6240 Website: *www.uoguelph.ca/labserv/units/soil-nutrient/*	Nick Schrier

Appendix D. Other Contacts

Agriculture & Agri-Food Canada Research Centres

Eastern Cereals and Oilseeds Research Centre
960 Carling Ave.
Ottawa, ON K1A 0C6
Tel: 613-759-1952
Website: *www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1180546650582&lang=e*

Greenhouse and Processing Crops Centre
2585 County Road 20
Harrow, ON N0R 1G0
Tel: 519-738-2251
Website: *www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1180624240102&lang=e*

Southern Crop Protection and Food Research Centre
1391 Sandford St.
London, ON N5V 4T3
Tel: 519-457-1470
Website: *www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1180640801098&lang=e*

Vineland Research Farm
4902 Victoria Ave. N.
Vineland, ON L0R 2E0
Tel: 905-562-4113

Delhi Research Farm
P.O. Box 186, Schafer Road
Delhi, ON N4B 2W9
Tel: 519-582-1950

Canadian Food Inspection Agency Regional Offices (Plant Protection)

www.inspection.gc.ca/english/toce.shtml

Belleville
345 College St. E.
Belleville, ON K8N 5S7
Tel: 613-969-3332

Brantford
625 Park Rd. N., Unit 6
Brantford, ON N3T 5L8
Tel: 519-753-3478

Hamilton
709 Main St. W., Suite 101
Hamilton, ON L8S 1A2
Tel: 905-570-8265

London
1200 Commissioners Rd. E., Unit 19
London, ON N5Z 4R3
Tel: 519-645-4021
Fax: 519-691-1315

Niagara Falls
P.O. Box 9, 350 Ontario St., Unit 13
St. Catharines, ON L2R 5L8
Tel: 905-357-5981

Ottawa District
38 Auriga Dr., Room 8
Ottawa, ON K2E 8A5
Tel: 613-274-7374, ext. 221

Toronto
1124 Finch Ave. W., Unit 2
Downsview, ON M3J 2E2
Tel: 416-665-5055
Fax: 416-665-5069

University of Guelph

Main Campus
Guelph, ON N1G 2W1
Tel: 519-824-4120
Website: *www.uoguelph.ca*

Alfred College
Alfred, ON K0B 1A0
Tel: 613-679-2218
Fax: 613-679-2423
Website: *www.alfredc.uoguelph.ca*

Kemptville College
Kemptville, ON K0G 1J0
Tel: 613-258-8336
Fax: 613-258-8384
Website: *www.kemptvillec.uoguelph.ca*

Ridgetown College
Ridgetown, ON N0P 2C0
Tel: 519-674-1500
Website: *www.ridgetownc.on.ca*

Department of Plant Agriculture
Website: *www.plant.uoguelph.ca*

Department of Plant Agriculture, Guelph
50 Stone Rd. E.
Guelph, ON N1G 2WI
Tel: 519-824-4120, ext. 56083
Fax: 519-763-8933

Department of Plant Agriculture, Simcoe
P.O. Box 587, 1283 Blueline Rd.
Simcoe, ON N3Y 4N5
Tel: 519-426-7127
Fax: 519-426-1225

Department of Plant Agriculture, Vineland
P.O. Box 7000, 4890 Victoria Ave. N.
Vineland Station, ON L0R 2E0
Tel: 905-562-4141
Fax: 905-562-3413

Lab Services Division
Website: *www.uoguelph.ca/labserv*
Pesticide and Trace Contaminants
P.O. Box 3650, 95 Stone Rd. W.
Guelph, ON N1H 8J7
Tel: 519-767-6200
Pest Diagnostic Clinic
Tel: 519-767-6256

Vineland Research and Innovation Centre

P.O. Box 4000, 4890 Victoria Ave. N.
Vineland Station, ON L0R 2E0
Tel.: 905-562-0320
Fax: 905-562-0084
Website: *www.vinelandontario.ca*

Appendix E. Diagnostic Service

Samples for disease diagnosis, insect or weed identification, nematode counts and *Verticillium* testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Rd. W.
Guelph, ON N1H 8J7
Tel: 519-767-6256
Fax: 519-767-6240
Email: pdc@lsd.uoguelph.ca
Payment must accompany samples at the time of submission.
Submission forms are available at:
www.labservices.uoguelph.ca/units/pdc/

Fee schedule

To obtain information on the fee schedule, refer to: *www.labservices.uoguelph.ca/units/pdc/* or phone the Pest Diagnostic Clinic.

How to sample for nematodes

Soil

When to sample
Soil and root samples can be taken at any time of the year that the soil is not frozen. In Ontario, nematode soil population levels are generally at their highest in May and June, and again in September and October.

How to sample soil
Use a soil sampling tube, trowel or narrow-bladed shovel to take samples. Sample soil to a depth of 20–25 cm (8–10 in.). If the soil is bare, remove the top 2 cm (1 in.) prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of 0.5–1 L (1 pint–1 quart) from this. No single sample should represent more than 2.5 ha (6.25 ac). Mix subsamples in a clean pail or plastic bag.

Sampling pattern
If living crop plants are present in the sample area, take samples within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of subsamples
Based on the total area sampled:

500 m² (5,400 ft²)	10 subsamples
500 m²–0.5 ha (5,400 ft²–1.25 ac)	25 subsamples
0.5 ha–2.5 ha (1.25–6.25 ac)	50 subsamples

Roots

From small plants, sample the entire root system plus adhering soil. For large plants 10–20 g (½–1 oz.), dig fresh weight from the feeder root zone and submit.

Problem areas

Take soil and root samples from the margins of the problem area where the plants are still living. If possible, also take samples from healthy areas in the same field. If possible, take both soil and root samples from problem and healthy areas in the same field.

Sample handling

Soil samples
Place in plastic bags as soon as possible after collecting.

Root samples
Place in plastic bags and cover with moist soil from the sample area.

Storage
Store samples at 5–10°C (40–50°F) and do not expose them to direct sunlight or extreme heat or cold (freezing). Only living nematodes can be counted. Accurate counts depend on proper handling of samples.

Submitting plant for disease diagnosis or identification

Sample submission forms

Forms can be obtained from your local Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) office. Carefully fill in all of the categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past three years and pesticide use records from this year.

Choose a complete, representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system or several plants showing a range of symptoms. If symptoms are general, collect the sample from an area where they are of intermediate severity. Completely dead material is usually inadequate for diagnosis.

With plant specimens submitted for identification, include at least a 20–25-cm sample of the top portion of the stem with lateral buds, leaves, flowers or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid the soil drying out and contaminating the leaves. Do not add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery

Deliver to the Pest Diagnostic Clinic as soon as possible by first class mail or courier at the beginning of the week.

Submitting insect specimens for identification

Collecting samples

Place dead, hard-bodied insects in vials or boxes and cushion with tissues or cotton. Place soft-bodied insects and caterpillars in vials containing alcohol. Do not use water, as this results in rot. Do not tape insects to paper or send them loose in an envelope.

Place live insects in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.

UNIVERSITY of GUELPH LABORATORY SERVICES

SAMPLE SUBMISSION FORM

95 Stone Road West
Guelph, ON N1H 8J7
Tel: (519) 767-6256
Fax: (519) 767-6240
Web: www.uoguelph.ca/pdc

Pest Diagnostic Clinic

LABORATORY USE ONLY: **LS Form: SubP01/04/03** **Pg. 1 of 1**
Rec'd: By: ______ **Date Received:** ______
Delivered By: ☐ **Mail** ☐ **Courier** ☐ **In-Person**
LS Sample No: ______ **to** ______
Payment Rec'd: $ ______ **Receipt #:** ______

Submitted By:			Owner (if different from submitter):		
Business Name (if applicable):			Business Name (if applicable):		
Street:			Street:		
City:	Prov:	Postal Code:	City:	Prov:	Postal Code:
Tel: ( ) -	Fax: ( ) -		Tel: ( ) -	Fax: ( ) -	
Email:			Email:		

Unless otherwise indicated, report and invoice will be sent to submitter
Report to: ☐ Submitter ☐ Owner
Required Report Format: ☐ Fax ☐ E-Mail ☐ Mail
Invoice to: ☐ Submitter ☐ Owner Quotation #: ______
Purchase Order / U of G G/L code: ______

Services Required: ☐ Nematode Count ☐ Nematode Count from Roots ☐ SCN Cyst & Egg Count ☐ Plant Disease Diagnosis ☐ Insect Identification ☐ Plant Identification ☐ Verticillium Count

Plant or Host Affected:	Cultivar/Variety:	Grower/Field sample #:
	Location of Plant (i.e. greenhouse, field, orchard, garden, etc.):	

Size of Planting:
% of Plants Affected:
Symptoms First Appeared in Past: ☐ Days ☐ Weeks ☐ Months ☐ Years
Degree of Injury: ☐ Severe ☐ Moderate ☐ Light

Cropping History:
Future Crop:

Describe the problem in detail (i.e. symptoms, plant parts affected, distribution of symptoms):

Were chemicals applied? Please specify type of product(s) used and date(s) of application:

Additional comments and specific requests:

Additional Sheet(s) Attached: ☐

Appendix F. Pesticide Groups Based on Sites of Action

Insecticides

The classification scheme listed below is adapted from information developed by the Insecticide Resistance Action Committee Mode of Action Working Group. Products with the same group number have a similar mode of action. For details on this classification system, see *www.irac-online.org/wp-content/uploads/2009/09/MoA-classification_v6.3.3_28july09.pdf.*

Group #	Primary Site of Action	Group Name	Product name(s)
1A	• Acetylcholinesterase inhibitor	Carbamate	Sevin
1B	• Acetylcholinesterase inhibitor • Nerve action	Organophosphate	DDVP, Diazinon, Dibrom, Malathion, Orthene, Dursban/Pyrate, Cygon/Lagon, Imidan
2A	• GABA-gated chloride channel agonists • Nerve action	Cyclodiene organochlorines	Thiodan/Thionex
3A	• Sodium channel modulators • Nerve action	Pyrethroids	Ambush/Pounce, Decis/DeltaGard
		Pyrethrins	
4A	• Nicotinic acetylcholine receptor agonists • Nerve action	Neonicotinoids	Intercept, Tristar
4B	• Nicotinic acetylcholine receptor agonists • Nerve action	Nicotine	Nicotine
5	• Nicotinic acetylcholine receptor (n AChR) allosteric activators	Spinosyns	Success
6	• Chloride channel activators • Nerve and muscle action	Avermectins	Avid
7A	• Juvenile hormone mimics	Juvenile hormone analogues	Enstar II
7C	• Juvenile hormone mimics • Growth regulation	Pyriproxyfen	Distance
9B	• Selective homopteran feeding blockers	Pymetrozine	Endeavor
10A	• Mite growth inhibitors	Clofentezine	Apollo
11	• Microbial disruptors of insect midgut membranes	*Bacillus thuringiensis*	Bioprotec/Dipel/Thuricide/VectoBac
12B	• Inhibitors of mitochondrial ATP synthase • Energy metabolism	Organotin miticides	Vendex
15	• Inhibitors of chitin biosynthesis, type 0 • Growth regulation	Benzoyl urea	Dimilin
17	• Moulting disruptor • Growth regulation	Cyromazine	Citation
18	• Ecdysone receptor agonists	Diacylhydrazine	Confirm
20B	• Mitochondrial complex III electron transport inhibitors	Acequinocyl	Shuttle
21A	• Mitochondrial complex 1 electron transport inhibitors (METI) • Energy metabolism	METI insecticides and acaricides	DynoMite
23	• Inhibitors of acetyl CoA carboxylase • Lipid synthesis, growth regulation	Tetronic and Tetramic acid derivatives	Forbid
Un	• Compounds of unknown or uncertain mode of action[1]	Bifenazate	Floramite
		Dicofol	Kelthane

[1] A compound with an unknown or controversial mode of action, or an unknown mode of toxicity, will be held in category 'Un' until evidence becomes available to enable that compound to be assigned to a more appropriate mode of action class.

Fungicides

This classification scheme is adapted from information developed by the Fungicide Resistance Action Committee to distinguish fungicide groups according to their cross resistance behaviour. M = multi-site inhibitor, U = unknown mode of action and unknown resistance risk, NC = not classified. For further details on this classification system, see *www.frac.info/frac/publication/anhang/FRAC_Code_List_2010.pdf.*

Group #	**Primary Site of Action**	**Group Name**	**Product name(s)**	**Risk of Developing Resistance**
1	□-tubuline assembly in mitosis	Methyl benzimidazole carbamates	Senator	High
2	Affect cell division, DNA and RNA synthesis and metabolism	Dicarboximide	Rovral	Medium to high
3	C14 – demethylase in sterol biosynthesis	DMI (De-methylation Inhibitor) fungicides	Nova, Funginex	Medium
4	RNA synthesis	**PA** – fungicides (**P**henyl**A**mides)	Subdue Maxx	High
5	Δ^{14} – reductase and Δ^{8} –> Δ^{7} isomerase in sterol biosynthesis	Morpholine	Meltatox	Low to medium
11	Fungal respiration – complex III: cytochrome bc1	Qol-fungicides (Quinone outside Inhibitors)	Heritage, Compass	High risk
14	Lipid peroxidation (proposed)	Aromatic hydrocarbon	Botran, Quintozene	Low to medium
		Heteroaromatic	Truban	Low to medium
17	3-keto reductase, C4 – de-methylation	Hydroxyanilide	Decree	Low to medium
28	Cell membrane permeability, fatty acids (proposed)	Carbamate	Previcur	Low to medium
33	Unknown	Phosphonate	Aliette	Low
40	Phospholipid biosynthesis and cell wall deposition (proposed)	Carboxylic acid amides	Acrobat	Low to medium
44	Microbial disrupters of pathogen cell membranes	Microbial (*Bacillus* sp.)	Rhapsody	Low
M1	Multi-site contact activity	Inorganic	Phyton-27	Low
M3	Multi-site contact activity	Dithiocarbamates	Dithane M-45, Zineb	Low
M4	Multi-site contact activity	Phthalimide	Maestro, Supra Captan, Folpan	Low
M5	Multi-site contact activity	Chloronitrile	Daconil	Low
NC	Unknown	Diverse	MilStop, RootShield, Mycostop, Actinovate, PreStop, Contans	Unknown

Appendix G. The Metric System

Metric units

Linear measures (length)

10 millimetres (mm) = 1 centimetre (cm)

100 centimetres (cm) = 1 metre (m)

1,000 metres = 1 kilometre (km)

Square measures (area)

100 m × 100 m = 10,000 m^2 = 1 hectare (ha)

100 ha = 1 square kilometre (km^2)

Cubic measures (volume)

Dry measure

1,000 cubic millimetres (mm^3) = 1 cubic centimetre (cm^3)

1,000,000 cm^3 = 1 cubic metre (m^3)

Liquid measure

1,000 millilitres (mL) = 1 litre (L)

100 L = 1 hectolitre (hL)

Weight-volume equivalents (for water)

(1.00 kg) 1,000 grams = 1 litre (1.00 L)

(0.50 kg) 500 g = 500 mL (0.50 L)

(0.10 kg) 100 g = 100 mL (0.10 L)

(0.01 kg) 10 g = 10 mL (0.01 L)

(0.001 kg) 1 g = 1 mL (0.001 L)

Weight measures

1,000 milligrams (mg) = 1 gram (g)

1,000 g = 1 kilogram (kg)

1,000 kg = 1 tonne (t)

1 mg/kg = 1 part per million (ppm)

Dry–liquid equivalents

1 cm^3 = 1 mL

1 m^3 = 1000 L

Metric conversions

5 mL = 1 tsp

15 mL = 1 tbsp

28.5 mL = 1 fl. oz.

Application rate conversions (approximate)

Metric to imperial

litres per hectare × 0.09 = gallons per acre

litres per hectare × 0.36 = quarts per acre

litres per hectare × 0.71 = pints per acre

millilitres per hectare × 0.015 = fluid ounces per acre

grams per hectare × 0.015 = ounces per acre

kilograms per hectare × 0.89 = pounds per acre

tonnes per hectare × 0.45 = tons per acre

Imperial to metric

gallons per acre × 11.23 = litres per hectare (L/ha)

quarts per acre × 2.8 = litres per hectare (L/ha)

pints per acre × 1.4 = litres per hectare (L/ha)

fluid ounces per acre × 70 = millilitres per hectare (mL/ha)

tons per acre × 2.24 = tonnes per hectare (t/ha)

Pounds per acre × 1.12 = kilograms per hectare (kg/ha)

ounces per acre × 70 = grams per hectare (g/ha)

Liquid equivalents

litres/hectare *approximate gallons/acre*

50 L/ha = 5 gal./acre

100 L/ha = 10 gal./acre

150 L/ha = 15 gal./acre

200 L/ha = 20 gal./acre

250 L/ha = 25 gal./acre

300 L/ha = 30 gal./acre

Dry weight equivalents

grams or kilograms/hectare *ounces or pounds/acre*

100 g/ha = 1½ oz./acre

200 g/ha = 3 oz./acre

300 g/ha = 4¼ oz./acre

500 g/ha = 7 oz./acre

700 g/ha = 10 oz./acre

1.10 kg/ha = 1 lb./acre

1.50 kg/ha = 1¼ lb./acre

2.00 kg/ha = 1¾ lb./acre

2.50 kg/ha = 2¼ lb./acre

3.25 kg/ha = 3 lb./acre

4.00 kg/ha = 3½ lb./acre

5.00 kg/ha = 4½ lb./acre

6.00 kg/ha = 5¼ lb./acre

7.50 kg/ha = 6¾ lb./acre

9.00 kg/ha = 8 lb./acre

11.00 kg/ha = 10 lb./acre

13.00 kg/ha = 11½ lb./acre

15.0 kg/ha = 13½ lb./acre

Conversion tables – metric to imperial (approximate)

Length		
1 millimetre (mm)	=	0.04 inch
1 centimetre (cm)	=	0.40 inch
1 metre (m)	=	39.40 inches
1 metre (m)	=	3.28 feet
1 metre (m)	=	1.09 yards
1 kilometre (km)	=	0.62 mile
Area		
1 square centimetre (cm^2)	=	0.16 square inch
1 square metre (m^2)	=	10.77 square feet
1 square metre (m^2)	=	1.20 square yards
1 square kilometre (km^2)	=	0.39 square mile
1 hectare (ha)	=	107,636 square feet
1 hectare (ha)	=	2.5 acres
Volume (dry)		
1 cubic centimetre (cm^3)	=	0.061 cubic inch
1 cubic metre (m^3)	=	1.31 cubic yards
1 cubic metre (m^3)	=	35.31 cubic feet
1,000 cubic metres (m^3)	=	0.81 acre-foot
1 hectolitre (hL)	=	2.8 bushels
Volume (liquid)		
1 millilitre (mL)	=	0.035 fluid ounce
1 litre (L)	=	1.76 pints
1 litre (L)	=	0.88 quart
1 litre (L)	=	0.22 gallon (Imp.)
1 litre (L)	=	0.26 gallon (U.S.)
Weight		
1 gram (g)	=	0.035 ounce
1 kilogram (kg)	=	2.21 pounds
1 tonne (t)	=	1.10 short tons
1 tonne (t)	=	2,205 pounds
Pressure		
1 kilopascal (kPa)	=	0.15 pounds/in.^{2}
Speed		
1 metre per second	=	3.28 feet per second
1 metre per second	=	2.24 miles per hour
1 kilometre per hour	=	0.62 mile per hour
Temperature		
°F	=	(°C × 9/5) + 32

Conversion tables – imperial to metric (approximate)

Length		
1 inch	=	2.54 cm
1 foot	=	0.30 m
1 yard	=	0.91 m
1 mile	=	1.61 km
Area		
1 square foot	=	0.09 m^2
1 square yard	=	0.84 m^2
1 acre	=	0.40 ha
Volume (dry)		
1 cubic yard	=	0.76 m^3
1 bushel	=	36.37 L
Volume (liquid)		
1 fluid ounce (Imp.)	=	28.41 mL
1 pint (Imp.)	=	0.57 L
1 gallon (Imp.)	=	4.55 L
1 gallon (U.S.)	=	3.79 L
Weight		
1 ounce	=	28.35 g
1 pound	=	453.6 g
1 ton	=	0.91 tonne
Pressure		
1 pound per square inch	=	6.90 kPa
Temperature		
°C	=	(°F – 32) × 5/9

Handy metric conversion factor

litres per hectare × 0.4 = litres per acre

kilograms per hectare × 0.4 = kilograms per acre

Abbreviations

% = per cent (by weight)
ai = active ingredient
AP = agricultural powder
cm = centimetre
cm^2 = square centimetre
DG = dispersible granular
DF = dry flowable
DP = dispersible powder
E = emulsifiable
e.g. = for example
F = flowable
g = gram
Gr = granules, granular
ha = hectare
kg = kilogram
km/h = kilometres per hour
kPa = kilopascal
L = litre
m = metre
m^2 = square metre
mL = millilitre
mm = millimetre
m/s = metres per second
SC = sprayable concentrate
SP = soluble powder
t = tonne
W = wettable (powder)
WDG = water dispersible granular
WP = wettable powder

Emergency and First-Aid Procedures for Pesticide Poisoning

For a major spill, a theft or a fire involving a pesticide, call the Ministry of the Environment at
1-800-268-6060.

For pesticide poisonings and pesticide injuries, call the Poison Information Centre:
Toronto 1-800-268-9017
1-877-750-2233 (TTY)

PREVENT ACCIDENTS

- **Read the label.** Follow all the precautions the label recommends. Read the First Aid section of the label BEFORE you begin to handle any pesticide.
- **Make sure that someone knows** what pesticides you are working with and where you are.
- **Keep a file of labels and product Material Safety Data Sheets (MSDS) for the pesticides you use.** Make sure everyone knows where to find this in case of an emergency.
- **Post emergency numbers near all telephones.**
- **Keep clean water, paper towels, extra gloves and clean coveralls close by** in case you spill pesticide on yourself.

If someone has been working with pesticides and you see any possible symptoms of pesticide poisoning or injury, take emergency action immediately.

IF AN ACCIDENT OR POISONING HAPPENS

- Protect yourself from injury first.
- Stop the exposure to the pesticide. Move the victim away from the contaminated area.
- Check the four basic facts — identify the pesticide, the quantity, the route of entry and time of exposure.
- Call an ambulance or the Poison Information Centre.
- Start first aid. This is not a substitute for professional medical help.
- **Provide the label, MSDS sheet or container to emergency personnel** at the scene — or take it with you to the hospital. Do not transport pesticide containers in the passenger compartment of the vehicle.

FIRST AID

If a pesticide comes in contact with skin:

- remove all contaminated clothing; wash skin thoroughly with lots of soap and warm water
- dry skin well and cover with clean clothing or other clean material.

If pesticide comes in contact with eyes:

- hold eyelids open; wash the eyes with clean running water for 15 minutes or more.

If pesticide was inhaled:

- move the victim to fresh air and loosen tight clothing
- give artificial respiration if the victim is not breathing.

Do not breathe in the exhaled air from the victim — you could also be poisoned.

If a pesticide was swallowed:

- **call the Poison Information Centre IMMEDIATELY.**

Emergency numbers are listed at the front of each Bell telephone directory.

To obtain copies of this or any other OMAFRA publication, please order:

- online at www.serviceontario.ca/publications
- by phone through the ServiceOntario Contact Centre, Monday to Friday, 8:30 AM to 5:00 PM ET
  - 416-326-5300
  - 416-326-3408 (TTY)
  - 1-800-668-9938, toll-free across Canada
  - 1-800-368-7095 (TTY), toll-free across Ontario
- in person at ServiceOntario Centres across Ontario

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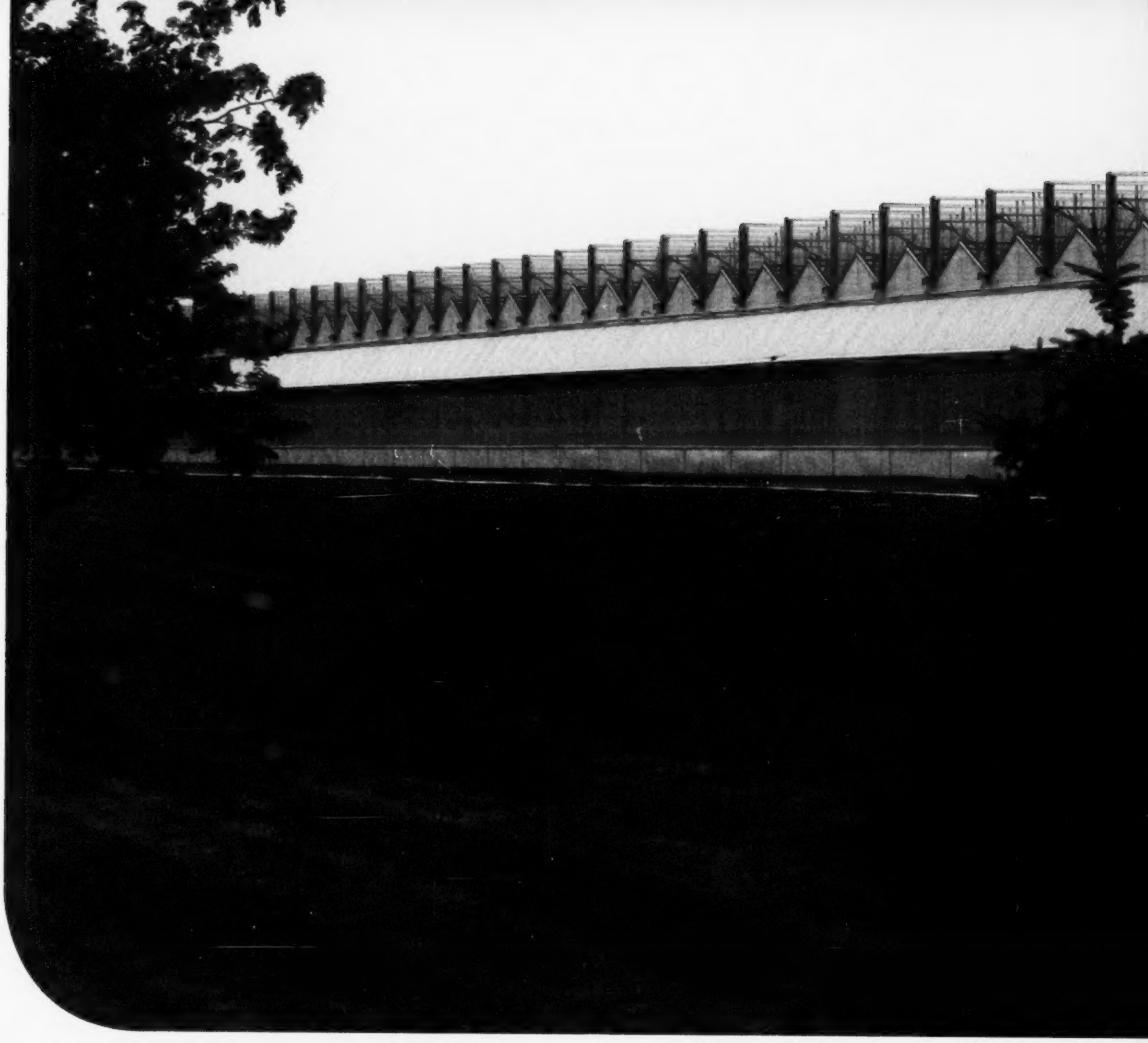

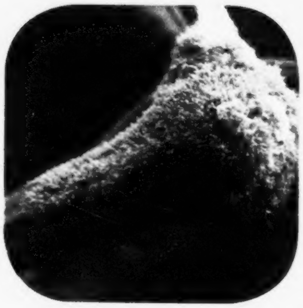

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